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## DELAYED INTERNAL FIXATION OF COMPOUND BATTLE FRACTURES IN THE MEDITERRANEAN THEATER OF OPERATIONS

A FOLLOW-UP STUDY IN THE ZONE OF INTERIOR

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### PART I

INITIAL SURGERY is the surgery which the war wounded receive in the hospitals of the combat zone as soon after wounding as is feasible. In compound fractures or soft-part wounds of the extremities, it is the excisional phase, or "débridement" (Anglicized usage), which is designed to save life and limb and prevent infection. Practically, it is the arrest of hemorrhage and the excision of tissue devitalized by the missile together with the adequate dressing and splinting of the extremity without effort at definitive reduction of a fracture.

Reparative surgery<sup>1</sup> is the secondary phase of military surgery performed in the Base Hospital, usually five to ten days after wounding. It is designed to prevent or cut short infection and to promote healing of the wound created by the missile and initial surgery. It is premised upon complete initial surgery resulting in a clinically clean wound when the latter is examined for repair. The principles of reparative surgery may be briefly stated as thorough wound visualization to determine the adequacy of initial surgery, excision of residual dead tissue, closure of wounds by suture or skin graft, the obliteration or dependent drainage of residual dead space and adequate splinting. Reparative surgery of compound fractures necessarily includes the adequate reduction and maintenance of reduction of the fractures. It includes the partial or complete closure of soft-part wounds compounding the fractures. Aerobic and anaerobic bacterial flora are recognized as present but the old concepts of avoiding surgery in a recognized bacterially infected field or of the "wound barrier against infection" are ignored.

The objectives of reparative surgery of compound fractures<sup>2</sup> are: 1. Minimum wound sepsis. 2. Maximum fracture reduction (maintained). 3. Rapid wound healing with minimum scar formation. 4. Maximum functional restoration of the extremity from wounds of muscle and nerve as well as bone.

In the Mediterranean Theater of Operations in an effort to achieve these objectives, adequate blood replacement therapy, routine systemic penicillin therapy and precision surgery are employed.

Prior to the days of reparative surgery, inadequate reduction had been

accepted in some cases, particularly in fractures about joints, fractures of the tibia and fibula and fractures of both bones of the forearm rather than risk stirring-up and establishing infection by an open operation, with or without internal fixation. An almost completely unconquered fracture problem was the segmental defect without contact of fragments which resulted from bone loss in some cases, particularly in the humerus. A pertinent observation of that period was that the unreduced, frequently manipulated or "adjusted," and, therefore, traumatized fracture, was often septic. As reparative surgery of compound fractures was conceived, it was planned that delayed internal fixation would be employed to achieve and maintain reduction in those fractures recognized as problems and in those in which reduction was not achieved by other methods. Following early successes as measured by fracture stabilization and wound healing, the procedure was extended to include many fractures whose contour permitted a rigid stabilization by plates or screws in order to gain the advantages offered by maximum reduction and stabilization of the fracture. The fractures permitting stabilization are in a definite minority, however, and other methods of management usually were employed. However, in some comminuted fractures, particularly those with bone loss, wire-loop fixations were used to achieve the best possible bony contact. Internal fixation is employed as an adjuvant of fracture management and fracture management comprises only one of the problems presented by a compound battle fracture.

A major problem of the management of battle fractures is the salvage of denuded external cortex of bone which will sequestrate unless soft parts become reattached and it thereby has a blood supply reestablished. If wound sepsis intervenes, soft parts do not readhere to the bone and sequestration is almost inevitable. Where sequestration occurs, wound healing does not occur. At the same time, fracture reduction must be achieved and maintained, projected towards bony union and the maximum functional restoration of the extremity. The well-reduced fracture is rarely septic and the compounding wounds are likely to heal under proper management. In view of these considerations, it seems reasonable to state that the *advantages* of delayed rigid internal fixation in the management of a compound battle fracture are: 1. Optimal apposition and alignment. 2. Elimination of the dead space of an unreduced fracture and its attendant traumatizing manipulations. 3. Early joint motion and muscle exercise may be permitted. 4. Multiple operating room procedures for concurrent injuries are permitted. 5. Staged procedures for the compounding wound are facilitated.

The *disadvantages* of delayed internal fixation in these injuries may be stated as follows: 1. Any periosteal stripping incident to the open reduction and placement of the metal potentially devitalizes the denuded cortex of bone. 2. The extent to which the metal interferes with the reattachment of soft parts to denuded bone enhances the chances of sequestration. 3. The trauma incident to the fixation, *e.g.*, retractor pull or vessel ligatures, may devitalize soft tissue and thereby establish a nidus for wound sepsis.

A nonrigid fixation as is offered by a wire loop maintains some degree of bony contact but otherwise minimizes both the advantages and disadvantages of internal fixation.

The use of delayed internal fixation in the Mediterranean Theater of Operations under the principles outlined began as a part of the reparative surgery of compound fractures in April, 1944, during the memorable days of Cassino shortly before the "Fall of Rome" and continued until the unofficial "V-M Day," when the Nazis in Italy surrendered. However, the excision of dead tissue, the closure of compounding wounds especially so as to cover denuded bone cortex and adequate drainage of residual dead space or unexcisable devitalized tissue, all designed to obviate sepsis and achieve wound healing are of greater importance in the program. Internal fixation would be doomed to failure if the other essential surgery were to be ignored.

The routine procedure for these casualties in a Base Hospital must be understood clearly. The operating room is set up for any possible indicated surgery on a compound fracture. The patient is usually properly prepared for reparative surgery five to ten days after wounding. He is anesthetized in the operating room where the encasement and dressing applied after initial surgery are removed. The extremity is cleansed, prepared and draped. The wound is visualized thoroughly by gentle retraction. Any residual dead tissue is excised and the depths of the wound are cleaned of old blood clot. The fracture site is exposed. It is there and then that internal fixation may be employed *as part of the first procedure of reparative surgery* if its advantages are obvious, *e.g.*, in condylar fractures of joints, oblique fractures of long bones which are easily reducible or segmental defects due to bone loss. Wound closure, usually with drainage, completes this stage of reparative surgery. In the great majority of cases reduction is attempted by traction or manipulation. If adequate reduction is not achieved and the contour of the fracture permits, internal fixation may be performed at another operation, perhaps after wound healing. Internal fixation has not been reserved for the ideal case but has been employed frequently in fractures that are major problems under any plan of management, *e.g.*, an avulsion of the soft parts of the arm exposing the shaft of the humerus for several inches, a grossly displaced septic fracture of the femur 66 days after wounding, with a huge soft-part wound—a situation hardly included in the realm of reparative surgery.

The results as observed in this Theater prior to evacuation of the patients to the Zone of Interior had been judged very satisfactory, particularly when they were viewed in the light of the problem for which the fixation was used. However, it was desired to know the facts. Upon the recommendation of the Surgeon, M.T.O., U.S.A., the author was ordered to the Zone of Interior and, with the approval and coöperation of the Surgery Division, Office of the Surgeon-General, a follow-up study on cases from this Theater was conducted.

#### PROCEDURE FOR THE SURVEY

Twenty-four designated General Hospitals were visited, and through the



coöperation of the Chiefs of Orthopedic Sections, patients in the hospital upon whom delayed internal fixation had been performed in the Mediterranean Theater of Operations, were examined on the wards or in clinics with their overseas and current records and roentgenograms. If the patients were on pass or furlough, their records were studied with the Chief of Section, or his ward officer. Clinical abstracts on patients already given a certificate of disability discharge, referred to Convalescent Hospitals, or discharged to duty, were studied. Five patients had fractures in two different bones in which internal fixation was employed. These are recorded as separate cases. From these observations, 300 complete case reports were assembled, providing the majority of the data for the compilation of the tables. Thirty-two additional patients were located as on duty, demobilized from the army or in Convalescent Hospitals not visited. This status gives reasonable assurance that their fractures are united and that their wounds are healed, therefore, the results are very satisfactory. They have been classified as "A" results in the appended tables, recording the results according to type fixation because the fixation used is known. They are not included in the tables recording the results according to indications but are added as Group X under "A" results.

The operative procedures were performed upon the 332 cases in 1944, in 18 Base Hospitals, by approximately 50 surgeons representing a cross-section of the surgical proficiency of the Theater. The great majority were performed between the "Fall of Rome," on June 4, 1944, and the conclusions of the Southern France and the Gothic Line Campaigns about November 1, 1944. This survey was conducted between March 16 and April 26, 1945.

#### EVALUATION OF RECORDED INDICATIONS

Particular study was made of the recorded indication and reason why the overseas surgeon chose delayed internal fixation as an adjuvant to fracture management and the results achieved and observed were evaluated in terms of the problems that required solution. The indications were divided arbitrarily into three groups: Obligate, desirable, and elective. Illustrative case histories are appended to illustrate each group and subgroup.

I. *Obligate*: Obligate indications were subdivided into five groups:

1. Bone loss producing a segmental defect without contact of fragments or a persistent distraction of fragments. Either, if allowed to persist, would be expected to result in nonunion. (Cases 1, 2, 3 and 4.)

2. The failure to achieve adequate reduction by traction or manipulative measures, a status expected to result in either nonunion, delayed union, or malunion unless improved. (Cases 3, 4, 5 and 6.)

3. Fractures about joints demanding reconstruction of joint congruity if a satisfactory result was to be expected. (Case 7.)

4. Massive soft-tissue loss precluding routine methods of management and demanding repeated staged procedures in an effort to achieve wound healing. (Case 8.)

5. Associated nerve injury, optimum management demanding early stabilization of fractures, possibly with deliberate shortening of the bone to permit approximation of nerve ends. (Case 9.)

The fixations in the obligate indications were performed either at the first operation of reparative surgery or at a later procedure, except the Obligate-2 subgroup. It, of necessity, represents a group fixed at a later operation.

II. *Desirables*: The desirable indications necessarily varied with the bone involved. All the fixations were performed at the first operation of reparative surgery.

1. *Femur*. It was considered desirable to stabilize fractures of the shaft if their contour permitted a reasonably rigid stabilization in anatomic reduction because by so doing, union in anatomic alignment could be anticipated, early motion of the knee joint would be permitted, and subsequent wound management by staged procedures would be facilitated. Moreover, these patients could be evacuated to the Zone of Interior within four to six weeks in preference to ten to 12 weeks after wounding, as was the average for fractures of the femur treated in skeletal traction, a factor of no little importance in a busy Theater of Operations. (Case 10.)

2. *Tibia and Fibula*. The desirable indications were fractures which permitted accurate reduction and stabilization by the use of two or more screws. In general, this group were oblique fractures, which, by experience, were difficult to maintain in adequate reduction by nonfixation measures. (Case 11.)

3. *Humerus*. No indications were classified as desirable.

4. *Radius and Ulna*. The desirable indications were all fractures fixed without obligate indications. Fractures of the forearm have proven difficult to reduce and stabilize, and the results achieved without internal fixation have not been satisfactory. Therefore, it was deemed desirable to achieve adequate reduction by means of internal fixation providing the contour of the fracture was favorable. (Case 12.)

III. *Elective*. Fixations performed at the first operation of reparative surgery in cases where the surgeon presumably chose internal fixation in preference to nonfixation methods without desirable or obligate indications.

1. *Femur*. All indications classified as elective were wire-loop fixations presumably used to insure contact of major comminuted fragments which otherwise might have caused some difficulty. (Case 13.)

2. *Tibia and Fibula*. Indications were classified as elective if they were neither obligate nor desirable. All the fixations classified in this group were platings except one which was a wire-loop. While this group is classified as elective, it is considered a rather strict classification because adequate reduction of fractures of the tibia and fibula has been very difficult to obtain by other measures. But because other measures were not tried initially and, therefore, the indications could not be classified as an Obligate-2, and because it has been previously considered hazardous to strip the periosteum for the application of a plate, the group has been classified as elective, in the sense that

PLATE I

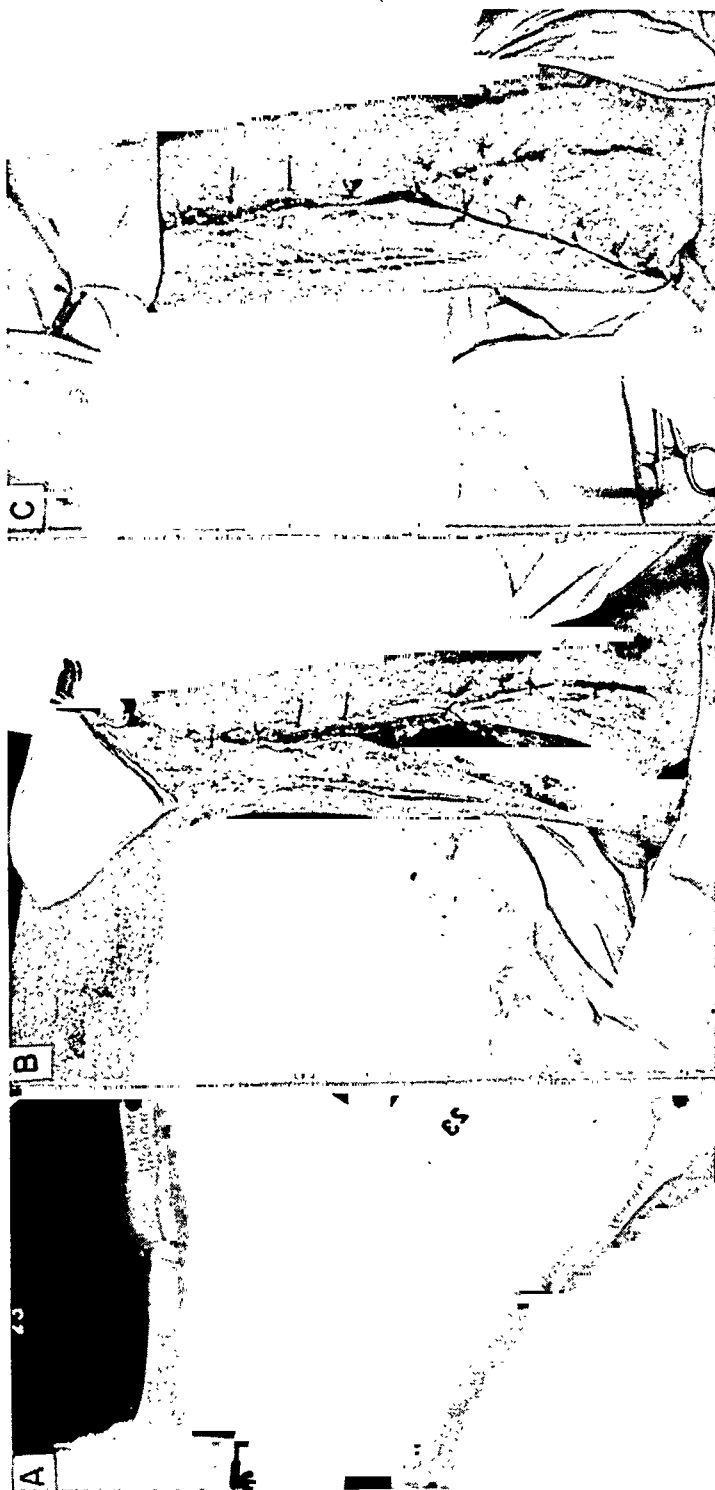


PLATE I.—Case 3: A. Roentgenograms, 13 March, 1944, one month after injury, with the extremity in skeletal traction, revealing distraction and gas abscess formation.

B. Partial wound closure and gaping dependent open wound for drainage at reparative surgery on 15 March, 1944.

C. Staged closure of the remaining portion of posterior wound over a small drain on 21 March, 1944.

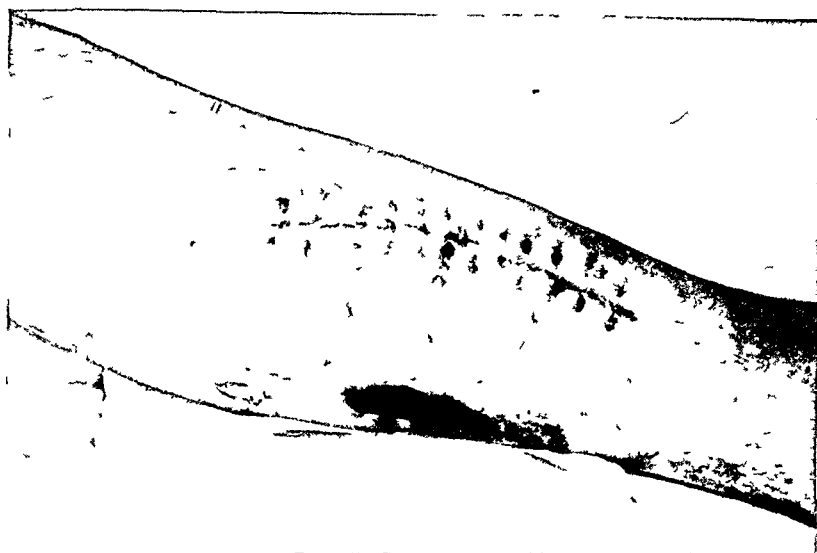


PLATE II.—Case 8: A. Compounding wounds of the right thigh at reparative surgery, 9 April, 1944.

B. The internal fixation by four screws. Minimal periosteal stripping was required.

C. Partial closure and loose packing of the dead space, with dependent drainage through a separate incision in the posterolateral fascial plane.

PLATE III



A



B



C

PLATE III.—Case 11: A. 15 July, 1944, four weeks after reparative surgery. Healed sutured wound over the tibia and the granulating relaxing incision. The latter might have been split-skin grafted.

B. The healed lateral wound through which drainage was established for a few days.

C. Roentgenograms made pre- and postoperative. The upper screw missed the drill hole in the distal cortex.

the operating surgeon elected to risk the hazard in order to achieve and maintain reduction. (Cases 14, 15, 16 and 17.)

3. *Humerus*. All indications that did not fall under the five subgroups of obligate were classified as elective. In general, the operating surgeon electively chose internal fixation as an adjuvant to fracture management without first attempting nonfixation methods. (Case 18.)

4. *Radius and Ulna*. No indications were classified as elective.

#### CLASSIFICATION OF RESULTS

It was found necessary to classify the results into six groups, taking into consideration union of the fracture, wound healing, with or without removal of the metal and sequestra, and whether either fractures or wound healing was delayed beyond average expectancy. Examples of each class are illustrated in the case histories.

*Result "A"*: This group represents the perfect results in which the fractures united in or near to anatomic alignment and the wound healed solidly, without sequestration or removal of the metal. (Cases 1, 4, 7, 9, 10, 11, 12, 15 and 18.) In several femurs and tibias, the metal was removed prophylactically even though the wounds were healed, either because it was routinely considered advisable by the surgeon in charge or there was evidence of absorption about the screws.

*Result "B"*: This group represents very satisfactory results because the fractures united in adequate reduction, and following removal of the sequestra and metal, wound healing was achieved without delay. (Cases 3, 5, 13 and 14.)

*Result "Bs"*: This subclass is necessary only in results of internal fixation of the tibia. Fracture union was achieved and, following removal of the sequestra and metal, the wounds healed, but the sequestration was massive and, therefore, full weight-bearing stability was delayed. (Case 16.) The end-results in these cases will be satisfactory, but the sequestration resulting was hazardous to bony continuity and stability prior to union, and the extremities required brace protection for several months.

*Result "C"*: This group represents anticipated satisfactory results as the fractures are united, but the wounds are not yet healed. In some, the sequestra and metal have not been removed. (Case 6.) Because wound healing has been achieved readily in the Result "B" group, wound healing is anticipated in these cases following indicated surgery. In the remainder, additional sequestrectomies and plastic procedures should achieve wound healing.

*Result "D"*: This group represents less favorable results as wound healing and, in the great majority, fracture union was not achieved until the sequestra and metal were removed, and the time required for both union and wound healing exceeded normal expectancy. (Case 8—humerus.)

*Result "E"*: This group includes the cases with healed wounds, without sequestration or removal of metal, but without union of the fracture. While the result cannot be considered completely satisfactory, the nonunion must be

evaluated against the chances of nonunion had internal fixation not been employed. (Case 2.)

*Result "F"*: This group is comprised by the bad results which must be evaluated also against probabilities of an unfavorable result had not the internal fixation been employed. The fractures did not unite and the wounds did not heal. In several, following removal of metal and sequestra, the wounds have healed, but bone grafting procedures will be necessary in an effort to achieve bone union. (Cases 17 and 8—radius-ulna.)

*Data*: The data is compiled in the appended tables. The results have been evaluated in relation to the type of fixation and to the indication. Emphasis has been placed upon indications because they represent the problem for the solution of which delayed internal fixation was chosen as an adjuvant to fracture management.

In Section III, a summary of all results except A and B is presented, and should be studied in an evaluation of this data.

It is regretted that no comparable data are available in similar groups treated without delayed internal fixation. An effort was made to obtain that information but none of the hospitals had them compiled or available.

#### I—RESULTS IN RELATION TO TYPE OF FIXATION

##### *Code of Results* (Summarized)

Result A—Union of the fracture and wound healing without sequestration or removal of metal.

Result B—Union of the fracture, and following removal of sequestra and metal, the wounds healed.

Result Bs—The same as B but the sequestration was massive, so as to prejudice the strength of the bone.

Result C—Union of the fracture but the wounds are as yet unhealed, however, in many, the metal and sequestra have not been removed.

Result D—Union of the fracture and wound healing after removal of metal and sequestra, but the time required for each was prolonged appreciably.

Result E—Nonunion of the fracture but wound healing without sequestration or removal of the metal.

Result F—Nonunion and sequestration without wound healing (in five cases the wounds healed after removal of sequestra and metal).

Three of the A results had angulated tibias but only in one case, a fracture of the lower third, was the angulation excessive. At the time of fixation, the fibula may be shortened one-quarter- to one-half-inch to allow for tibial collapse, especially in lower third fractures.

# COMPOUND BATTLE FRACTURES

TABLE A

Code of Results	FEMUR						Total	%
	A	B	C	D	E	F		
Plates	41 57%	12 <sup>a</sup> 16.6%	5 7%	5 7%	2 2.7%	7 9.7%	72 100%	49.3%
Screws	39 73.6%	7 <sup>b</sup> 13.2%	6 11.3%		1 <sup>c</sup> 1.9%		53 100%	36.3%
Wire	12 57.1%	5 <sup>d</sup> 24%			2 9.5%	2 9.5%	21 100%	14.4%
Totals	92 <sup>e</sup> 63%	24 16.4%	11 7.5%	5 3.4%	5 3.4%	9 6.1%	146 100%	100%

<sup>a</sup> One had rather heavy sequestration but grafting was not required.

<sup>b</sup> One had precarious union but original injury was severe, with bone loss.

<sup>c</sup> Only four months after injury—still in spica and may unite.

<sup>d</sup> One Parham band was used in this group.

<sup>e</sup> Operation was performed after wound healing in five cases. The average time since wounding in four cases was 35 days. The time-interval in the 5th case was not recorded.

TABLE B-1  
TIBIA-FIBULA

Code of Results	A	B	B-s <sup>b</sup>	C	D	E	F	Total	%
Plates	16 <sup>a</sup> 37.3%	10 23.3%	6 14%	2 4.7%		1 2.3%	8 18.6%	43 100%	57.3%
Screws	19 73%	2 <sup>a</sup> 7.7%	2 7.7%	3 11.5%				26 100%	34.6%
Wire	3 50%	2 <sup>a</sup> 33.3%					1 16.6%	6 100%	8.1%
Totals	38 <sup>e</sup> 50.7%	14 18.7%	8 10.7%	5 6.7%		1 1.3%	9 12%	75 100%	100%

<sup>a</sup> One "A" plate, one "B" screw and one "B" wire fixation were delayed in fracture and wound healing but not sufficiently long to warrant a "D" classification, and sequestration was *nil* or minimal.

<sup>b</sup> This subgroup united and wound healing was obtained after removal of metal and sequestra, but the sequestration was so massive that the union needed protection for several months, and there was danger of refracture.

<sup>e</sup> Operation was performed after wound healing in five cases. The average time since wounding in four cases was 28 days. The time-interval was not recorded in the 5th case.

TABLE B-2  
TIBIA-FIBULA

*Results of plating of fibula without fixation of the comminuted tibia. (The procedure maintains length, and, in effect, converts the fracture into one of the tibia only. Union of the fractures and healing of the compounding wounds of both the tibia and fibula are classified)*

Code of Results	A	B <sup>a</sup>	E
Total cases	13 100%	10 <sup>b</sup> 77%	1 7.7%
			2 <sup>c</sup> 15.4%

<sup>a</sup> The tibial fracture and wound healed. Sequestra and metal were removed from the fibula prior to wound healing.

<sup>b</sup> In the A results two cases required sequestrectomy of tibia before wound healing.

Three cases may need reinforcing bone grafts for stability because of bone loss at injury.

<sup>c</sup> A four-inch defect in tibia-length was strutted, anticipating a bone grafting prodedure. The other case was a nonunion of a tibia in which there was bone loss and minimal contact of fragments.



TABLE C  
HUMERUS

Code of Results	A	B	C	D	E	F	Total	%
Plates	16 <sup>a</sup> 64%	3 12%	1 4%	1 4%	1 4%	3 12%	25 100%	37.3%
Screws	10 71.4%	3 21.4%	1 7.2%				14 100%	20.9%
Wire	19 68%	2 7.2%	3 10.8%		3 10.8%	1 3.6%	28 100%	41.8%
Totals	45 <sup>b</sup> 67.2%	8 <sup>c</sup> 12.1%	5 7.4%	1 1.5%	4 <sup>d</sup> 5.9%	4 5.9%	67 100%	

<sup>a</sup> One was delayed in uniting but the wounds healed promptly.<sup>b</sup> In five cases, averaging 38 days since wounding, operation was performed after wound healing.<sup>c</sup> In one case operation was performed after wound healing, 20 days after wounding.<sup>d</sup> In one case operation was performed after wound healing, 25 days after wounding.TABLE D  
RADIUS-ULNA*(If the metals were mixed in a given case, the more massive metal is classified)*

Code of Results	A	B	C	D	E	F	Total	%
Plates	9 60%	2 13.4%			1 6.7%	3 20%	15 100%	48.4%
Screws	2 <sup>a</sup> 100%						2 100%	6.6%
Wire	10 71.4%	3 <sup>b</sup> 21.4%			1 7.1%		14 100%	45.0%
Totals	21 <sup>c</sup> 67.8%	5 16.1%			2 6.4%	3 9.6%	31 100%	

<sup>a</sup> One deliberate ulna shortening, to permit contact of radial fragments with bone loss, was not a good functional result because of soft-tissue fibrosis and synostosis.<sup>b</sup> One case was a fracture of both bones, each wired. Only the wire in the radius was removed.<sup>c</sup> In four cases, averaging 29 days after wounding, operation was performed after wound healing.TABLE E  
COMPOSITE FOR ALL BONES

Code of Results	A	B	Bs	C	D	E	F	Total	%
Plates (total)	92 54.8%	28 16.7%	6 3.6%	8 4.8%	6 3.6%	7 4.1%	21 12.4%	168 100%	50.6%
Femur	41	12		5	5	2	7	72	
Tibia-fibula	16	10	6	2		1	8	43	
Tibia-fibula (Fig. plating)	10	1				2		13	
Humerus	16	3		1	1	1	3	25	
Radius-ulna	9	2				1	3	15	
Screws (total)	70 73.8%	12 12.6%	2 2.1%	10 10.5%		1 1%		95 100%	28.6%
Femur	39	7		6		1		53	
Tibia-fibula	19	2	2	3				26	
Humerus	10	3		1				14	
Radius-ulna	2							2	
Wire (total)	44 63.8%	12 17.3%		3 4.3%		6 8.7%	4 5.8%	69 100%	20.8%
Femur	12	5				2	2	21	
Tibia-fibula	3	2					1	6	
Humerus	19	2		3		3	1	28	
Radius-ulna	10	3				1		14	
Grand total	206 61.5%	52 15.7%	8 2.4%	21 6.3%	6 1.8%	14 4.2%	25 7.5%	332 100%	

II—RESULTS IN RELATION TO INDICATIONS

*Code of Indications*  
(Summarized)

*Obligates:* Fixations were at either first, or later, operation of reparative surgery.

- 1—Bone loss producing a segmental defect or persistent distraction, either of which accepts nonunion as almost inevitable.
- 2—Inadequate reduction by nonfixation measures, *e.g.*, skeletal traction, "hanging cast," manipulation.
- 3—Condylar fractures at knee or elbow.
- 4—Massive soft-tissue loss which demanded repeated staged procedures and, preferably, a fixed fracture.
- 5—Associated nerve trunk injuries, the optimum management of which required fracture fixation.

*Desirable:* All fixations were at first operation of reparative surgery.

Femur—Rigid stabilization by plates or screws, nonobligate.

Tibia-fibula—Rigid stabilization by screws only, nonobligate.

Radius-ulna—All type fixations that were nonobligate.

*Elective:* All fixations were at first operation of reparative surgery.

Femur—All wire-loop fixations, nonobligate.

Tibia-fibula—All platings (including fibula platings) and wire-loops, nonobligate.

Humerus—All type fixations that were nonobligate.

Group X, representing 32 cases of known favorable (A) results but unknown indications, is not included in the tables in this section except as added A results.

TABLE F  
FEMURS

Code of Results	A	B	C	D	E	F	Total	
Obligates:								
1	5				2	1	8	
1 and 2	3		1				4	
1 and 4		1	1			1	3	
2 <sup>a</sup>	16	4	5	2	1	5	33	
3	6	2					8	
4	1						1	
Total obligates	31	7	7	2	3	7	57	(41.9%)
Desirable	49	13	4	3	1	2	72	(53.0%)
Elective <sup>c</sup>	2	4			1		7	(5.1%)
Total	82	24	11	5	5	9	136	(100%)
Group X <sup>d</sup>	10						10	
Grand total	92	24	11 <sup>b</sup>	5	5	9	146	
	(63%)	(16.4%)	(75%)	(3.4%)	(3.4%)	(6.3%)	(100%)	

<sup>a</sup> The Obligate-2 indications averaged 32 days from wounding to the surgery for the fixation, indicating 20 to 25 days in traction without reduction.

<sup>b</sup> This group now average only seven months since wounding.

<sup>c</sup> All elective fixations were wire-loops.

<sup>d</sup> Results but not indications are known.

TABLE G  
TIBIA-FIBULA

Code of Results	A	B	Bs <sup>a</sup>	C	D	E	F	Total	
Obligates									
1	2	1					1	4	
2	4	4		2		1	2	13	
3	1							1	
Total obligates	7	5		2		1	3	18	(29.5%)
Desirable (all screws)	11	2	2	2				17	(27.8%)
Elective <sup>c</sup> (25 platings, 1 wire)	6	7	6	1			6	26	(42.7%)
Total	24	14	8	5		1	9	61	(100%)
Group X <sup>d</sup>	14							14	
Grand total	38	14	8 <sup>a</sup>	5		1	9	75 <sup>b</sup>	
	(50.7%)	(18.7%)	(10.7%)	(6.7%)		(1.3%)	(12%)	(100%)	

\* This subgroup united and wound healing was obtained after removal of metal and sequestra, but the sequestration was so massive that the union needed protection for several months, and there was danger of refracture.

<sup>b</sup> Thirteen were compound fractures due to injury rather than a penetrating missile. The results achieved in this group by plating (11), and multiple screws (2), were as follows:

A	B	Bs	C	D	E	F
3	3	3	2		1	1

<sup>c</sup> Platings of the fibula are classified as elective indications but they are not included in this table.

<sup>d</sup> Results but not indications are known.

TABLE H  
HUMERUS

Code of Results	A	B	C	D	E	F	Total	
Obligates:								
1	7		1		3	1	12	
1 and 2	2						2	
1 and 4						2	2	
2	10	4	2		1		17	
3	4	2					6	
4				1		1	2	
5	1						1	
Total obligates	24	6	3	1	4	4	42	(66.6%)
Elective	17	2	2				21	(33.3%)
Total	41	8	5	1	4	4	63	(100%)
Group X <sup>a</sup>	4						4	
Grand totals	45	8	5	1	4	4	67	
	(67.2%)	(12%)	(7.4%)	(1.5%)	(5.9%)	(5.9%)	(100%)	

<sup>a</sup> Results but not indications are known.

# COMPOUND BATTLE FRACTURES

TABLE I  
RADIUS-ULNA

Code of Results	A	B	C	D	E	F	Total	
Obligates:								
1	1				1		2	
1 and 2		1					1	
1 and 4		1					1	
2	8	2					10	
2 and 4	1					1	2	
4						1	1	
5	1						1	
Total obligates	11	4			1	2	18	(66.6%)
Desirable	6	1			1	1	9	(33.3%)
Total	17	5			2	3	27	(100%)
Group X*	4						4	
Grand totals	21 (67.8%)	5 (16.1%)			2 (6.4%)	3 (9.6%)	31 (100%)	

\* Results but not indications are known.

TABLE J  
A SUMMARY OF RESULTS IN OBLIGATE INDICATIONS  
(135 cases—45%)

Obligate-1—39 cases with bone loss producing a segmental defect or with persistent distraction either accepting nonunion as almost inevitable. In seven, previous efforts at reduction were unsuccessful. In eight, soft-tissue loss added to the indication.

Code of Results	A	B	C	D	E	F	Total	%
Total Obligate—1	20 51.3%	4 10.2%	3 7.7%		6 15.4%	6 15.4%	39 100%	28.9%
Femur	(8)	(1)	(2)		(2)	(2)	(15)	
Tibia-fibula	(2)	(1)				(1)	(4)	
Humerus	(9)		(1)		(3)	(3)	(16)	
Radius-ulna	(1)	(2)			(1)		(4)	

Obligate-2—75 cases without adequate reduction by the nonintervention methods of skeletal traction, "hanging cast" or manipulative measures followed by immobilization.

Code of Results	A	B	C	D	E	F	Total	%
Total Obligate—2	39 52%	14 18.7%	9 12%	2 2.6%	3 4%	8 10.6%	75 100%	55.5%
Femur	(16)	(4)	(5)	(2)	(1)	(5)	(33)	
Tibia-fibula	(4)	(4)	(2)		(1)	(2)	(13)	
Humerus	(10)	(4)	(2)		(1)		(17)	
Radius-ulna	(9)	(2)				(1)	(12)	

Obligate-3—15 condylar fractures in which optimum reduction could be achieved and maintained only by some form of fixation at open operation.

Code of Results	A	B	C	D	E	F	Total	%
Total Obligate—3	11 73.3%	4 26.7%					15 100%	11.1%
Femur	(6)	(2)					(8)	
Tibia-fibula	(1)						(1)	
Humerus	(4)	(2)					(6)	

Obligate-4—4 cases with the soft-tissue loss so great, and demanding such attention, that some fixation was deemed necessary (see Obligate-1 above also).

Code of Results	A	B	C	D	E	F	Total	%
Total Obligate—4	1 25%			1 25%		2 50%	4 100%	3%
Femur	(1)						(1)	
Humerus				(1)		(1)	(2)	
Radius-ulna						(1)	(1)	

Obligate-5—2 cases with associated nerve injuries, the optimum management requiring fracture fixation.

Code of Results	A	B	C	D	E	F	Total	%
Total Obligate—5	2 100%						2 100%	1.5%
Humerus	(1)						(1)	
Radius-ulna	(1)						(1)	
Total obligates	73 54.1%	22 16.3%	12 8.9%	3 2.2%	9 6.4%	16 11.6%	135 100%	100%

TABLE K

SUMMARY OF RESULTS IN DESIRABLE INDICATIONS

(98 Cases—32.7%)

*All fixations were performed at the first operative procedure of reparative surgery*

Femur—72 cases in which it was desired to gain the advantages of a well-reduced and stabilized fracture of the femur by plating or multiple screws. Several cases actually were not stabilized but the indications were classified as desirable.

Tibia-fibula—17 cases of fracture of the tibia and fibula in which it was desired to obtain the complete reduction and stabilization afforded by open reduction and multiple screw fixation.

Humerus—

Radius-ulna—9 cases in which it was desired to obtain maximum reduction at reparative surgery rather than risk an inferior reduction by other measures.

Code of Results	A	B	Bs	C	D	E	F	Total
Femur	49	13		4	3	1	2	72
Tibia-fibula	11	2	2	2				17
Humerus								
Radius-ulna	6	1				1	1	9
Total	66 (67.4%)	16 (16.3%)	2 (2%)	6 (6.1%)	3 (3%)	2 (2%)	3 (3%)	98 (100%)

## COMPOUND BATTLE FRACTURES

TABLE L  
SUMMARY OF RESULTS IN ELECTIVE INDICATIONS  
(67 Cases—22.3%)

*All fixations were performed at the first operative procedure of reparative surgery when it was elected to use internal fixation as a means or adjunct of maintaining fracture reduction in preference to other measures.*

Code of Results	A	B	Bs	C	D	E	F	Total
<b>Bone</b>								
<b>Femurs</b>								
(all wire fixations)	2	4				1		7
Tibia-fibula (25 plate and 1 wire fixations)	6	7	6	1			6	26
Fibula fixations (all plates)	10	1				2		13
Humerus (6 plates, 6 screws and 9 wire fixations)	17	2		2				21
Radius-ulna								
Total	35 (52.2%)	14 (20.8%)	6 (8.9%)	3 (4.5%)		3 (4.5%)	6 (8.9%)	67 (100%)

## COMPOSITE RESULTS IN FIXATIONS FOR WHICH INDICATION HAS BEEN RECORDED

Code of Results	A	B	Bs	C	D	E	F	Total
Totals	174 (58%)	52 (17.3%)	8 (2.7%)	21 (7%)	6 (2%)	14 (4.7%)	25 (8.3%)	300 (100%)
Group X	32							32
Grand total	206 (62.1%)	52 (15.7%)	8 (2.4%)	21 (6.3%)	6 (1.8%)	14 (4.2%)	25 (7.5%)	332 (100%)

III—SUMMARY OF ALL RESULTS NOT CLASSED AS EXCELLENT (A)  
OR VERY SATISFACTORY (B)

*(Except the Bs-group previously discussed)*

TABLE M  
C RESULTS—21 CASES  
*(The fractures are united but the wounds are unhealed)*

<i>Femur—11 cases.</i>	Cases	Fixation
Indications—Obligate—(1, 2)—Bone loss and faulty reduction.....	1	Plate
Obligate—(1, 4)—Bone and soft tissue loss.....	1	Plate
Obligate—(2) —Faulty reduction.....	5	Plate
Desirable.....	4	Screws
	11	

Average time since wounding until observed (11 cases) was seven months.

In five cases the metal and sequestra remain. Eventual satisfactory results are anticipated after appropriate surgery.

In one case, only four months since wounding, the metal and sequestra were removed three days before he was seen. He will probably become a B result in two to three weeks.

In one case, an obligate-I, 4 indication, the soft-tissue loss was so massive that bone has been exposed since injury. Following plating, union has

occurred. The failure of wound healing is the result of the injury, not the fixation.

In four remaining cases, further sequestrectomies and plastic surgery may be required.

<i>Tibia-fibula</i> —5 cases.	Cases	Fixation
Indications—Obligate—(2).....	2	Screws
Desirable.....	2	Screws
Elective.....	1	Plate

Union of the fracture was delayed in three cases. Sequestration was massive in one case and heavy in two others. In these, reinforcing grafting may be necessary.

<i>Humerus</i> —5 cases.	Cases	Fixation
Indications—Obligate—(1) (bone loss).....	1	Wire
Obligate—(2) (faulty reduction).....	2	Plates
Elective.....	2	Wire
	<hr/> 5	

The one case of bone loss was a wire-loop fixation by which a 1.5-inch defect was overcome. Union alone in this case is an excellent achievement.

*Radius-ulna*—None.

*Appraisal*—Eventual satisfactory results after appropriate surgery.

TABLE N  
D RESULTS—6 CASES

(The fractures united and the wounds healed after removal of sequestra and metal, but the time for each was prolonged appreciably)

<i>Femur</i> —5 cases. (All were plate fixations)	Cases
Indications—Obligate—(2) (faulty reduction).....	2
Desirable.....	3
	<hr/> 5

Average time from wounding until it could be verified that the fractures were united and wounds healed was nine months.

*Tibia-fibula*—None.

*Humerus*—1 case. (Plate fixation)

Indication—Obligate—4—a massive soft-tissue loss.

The union achieved is precarious. This case was a severe upper extremity injury with a massive septic wound of a compound fracture of the upper third of the radius and ulna which was also fixed internally, with a failure resulting.

*Radius-ulna*—None.

*Appraisal*—Unsatisfactory results but not complete failures. There are no comparable data available on nonfixation cases with which to compare this incidence.

# COMPOUND BATTLE FRACTURES

TABLE O  
E RESULTS—14 CASES

(The fractures did not unite but the wounds healed without sequestration or removal of metal)

Femur—5 cases.	Cases	Fixation
Indications—Obligate—(1) (bone loss).....	2 <sup>a</sup>	1 plate—1 wire
Obligate—(2) (faulty reduction).....	1 <sup>b</sup>	Plate
Desirable.....	1 <sup>c</sup>	Screw and wire
Elective.....	1 <sup>d</sup>	Wire
	5	

<sup>a</sup> Nonunions were probably inevitable without the use of internal fixation.

<sup>b</sup> A large rotated central fragment which could not be reduced (a double fracture). The proximal fracture united. The distal may go on to union. The internal fixation here was very advantageous.

<sup>c</sup> A mildly comminuted fracture of femur which was only partially stabilized by screws and a wire-loop in the presence of sepsis (associated amputation of foot on same side and of leg on opposite side) is now only four months after injury. The fracture may unite.

<sup>d</sup> A severely comminuted septic lower third fracture of the femur (a septic knee associated). Wire-loops were used to hold major fragments approximated and the fracture site was drained dependently. The nonunion which followed cannot be attributed to the internal fixation.

## Tibia-fibula—I case.

Indication—Obligate-2 (faulty reduction).. This case was plated with distraction as determined by the overseas roentgenograms. The nonunion can be attributed to this error in technic.

Tibia-fibula (fibula plated)—2 cases. See footnotes, Table B-2.

Humerus—4 cases.	Cases	Fixation
Indications—Obligate—(1) (bone loss).....	3 <sup>a</sup>	Wire
Obligate—(2) (faulty reduction)	1 <sup>b</sup>	Plate

<sup>a</sup> Union was obtained in ten similar cases by internal fixation (see above table).

<sup>b</sup> Operation was 25 days after wounding and after the wound had healed.

Radius-ulna—2 cases.	Cases	Fixation
Indications—Obligate—(1) (bone loss).....	1 <sup>a</sup>	Wire
Desirable.....	1 <sup>b</sup>	Plate

<sup>a</sup> A one-inch segmental defect in the radius with an intact ulna. A wire-loop was inserted to help maintain alignment, without hope of union.

<sup>b</sup> A double fracture of the ulna and a fracture of the radius. A Steinman pin passed down the medullary canal of the ulna was removed after three weeks. The radius was plated. The ulna failed to unite at each fracture. Actually, poor reduction was obtained. The radius may yet unite.

Appraisal—Satisfactory insofar as the hazard of sequestration is concerned.

1. Improved by use of fixation.....	4
2. Unimproved but not retarded.....	9
3. Retarded ?—(faulty technic).....	1 = 0.3% of 332 cases
	14

TABLE P  
F RESULTS—25 CASES

(Nonunion, with sequestration and without wound healing until, in five cases after removal of sequestra and metal, the wounds healed. Because this group are the "failures," each case is abstracted)

Femur—Nine cases.

Case 1 (Obligate—bone loss).—At reparative surgery on the eighth day after wounding a fracture of the lower third of the femur exhibited a large segmental defect



without contact of fragments. The surgeon's note stated that reduction could be maintained only by internal fixation so the femur was plated. There was further sequestration of approximately 1.5 inches of bone. Following removal of metal and sequestra, the wound healed. The fixation undoubtedly contributed to the sequestration and delayed wound healing but nonunion was inevitable without it.

**Case 2 (Obligate—bone loss).**—If amputation had been performed, it could not have been criticized as there was extensive bone and soft-tissue loss. Several wire loops were used to keep some of the larger fragments approximated. The result can be in no way attributed to the fixation.

**Case 3—(Obligate—faulty reduction).**—On the 32nd day after wounding, in the presence of sepsis and at surgery for a secondary hemorrhage, a faulty reduction of a subtrochanteric fracture was corrected. One large comminuted fragment was fixed by screws to the upper fragment and it united. The lower fragment was held approximated to the upper by a wire loop, but the contact was poor and the surgeon's note stated that he anticipated nonunion. The sequestra and metal have been removed in the Z. of I. At this time the wound is healed except for a raw area in the massive scar.

**Case 4 (Obligate—faulty reduction).**—On the 23rd day after wounding, a comminuted upper third of the femur was plated in reduction. Three months later metal and sequestra were removed. The extremity was placed in skin traction. Roentgenograms, one month and two months later, show progressive bowing, and for that reason this case is called a nonunion. He is now, six months after fixation, in a spica, and the fracture may unite. The wounds are about healed. It is difficult to compare the present result with what could have been anticipated without internal fixation.

**Case 5 (Obligate—faulty reduction).**—On the 28th day after wounding, in the presence of established sepsis, the femur was plated. A six-hole plate with only four screws and with one transfixion screw was the fixation. On postoperative roentgenologic examination, the fixation does not appear stable. The metal and sequestra were removed 2.5 months later in the Z. of I., after which the wound healed, but at this time (5.5 months since fixation) there is no union. The fixation here was of minimum benefit although it held position. It probably contributed to the sequestration.

**Case 6 (Obligate—faulty reduction).**—On the 17th day after wounding, through a septic wound, the comminuted fracture of the midshaft was plated in reduction. A study of the roentgenograms indicates that the fracture might have been reduced in traction. The result is considered a complete failure and the fixation probably contributed to it.

**Case 7 (Obligate—faulty reduction).**—On the 66th day after wounding, following a sepsis so severe that amputation was considered, the widely separated femoral fragments were plated, but the operative note states that stabilization was not achieved. The result would probably have been the same had the fixation not been performed.

**Case 8 (A desirable).**—On the sixth day after wounding, a midthird fracture was plated. Two months later, in the Z. of I., the plate and sequestra were removed, after which the wound healed. At this time, six months after fixation, there is no union. The result here is not good. Perhaps the metal was removed prematurely.

**Case 9 (A desirable).**—On the seventh day after wounding, a midthird fracture was plated. The metal and sequestra were removed three months later in the Z. of I. At this time, six months after fixation, the extremity is in traction. Only a small sinus remains and it is thought that the fracture is uniting. An optimistic evaluation would have placed this case as a D result, delayed. However, the result is not satisfactory.

#### *Tibia-fibula—Nine cases.*

**Case 1 (Obligate—faulty reduction).**—A double fracture was plated. The proximal only united. Sequestra and metal were removed.

**Case 2 (Elective).**—A wire loop was probably of benefit. The fragments are in excellent approximation and, as it is only four months since wounding, union is expected.

## COMPOUND BATTLE FRACTURES

**Case 3 (Elective).**—Only three months have elapsed since wounding, but sequestra and a plate have been removed. Union may occur.

**Cases 4-9** (Four electives and two obligates—one for bone loss, one for faulty reduction). *All were plate fixations.* The sequestration was massive, wound healing is not achieved, and the resultant scar will be excessive. These are failures in every sense and the surgery contributed directly to the prolonged disability. Bridging bone grafts will be necessary in several.

*Humerus*—Four cases.

**Case 1** (Obligate—bone loss).—A wire loop fixation.

**Case 2** (Obligate—massive soft-tissue loss).—A plating.

**Cases 3-4** (Obligate—bone and soft-tissue loss).—These were platings. Sequestration was not severe.

All were probably doomed to nonunion regardless of the fixation.

*Radius-ulna*—Three cases. (All fixations were platings.)

**Case 1** (Obligate—soft-tissue loss plus faulty reduction).—Also had a severe fractured humerus which was fixed with a D result, as described above. The ulna was plated 39 days after wounding, in the presence of established sepsis, because the reduction was poor and the soft-tissue wound demanded repeated staged procedures. Neither the bone nor the metal could be covered by soft parts. The result to date cannot be attributed to the fixation but any periosteal stripping that was done may have contributed to the sequestration.

**Case 2** (Obligate—massive soft-tissue loss).—A plating of a radius with a concurrent massive loss of ulna. Union did not occur and there was some sequestration.

**Case 3** (Desirable).—A plating of a double fracture of the radius with some soft-tissue loss. Neither bone nor wound healing occurred. The indication here was almost an obligate.

*Appraisal:* Failures with qualifications.

1. Improved by fixation . . . . .	2
2. Unimproved but <i>not</i> retarded . . . . .	8
3. Retarded . . . . .	13 = 3.9 per cent of 332 cases
4. Not classifiable at this time . . . . .	2
	—
	25

### ADDITIONAL OBSERVATIONS AND DATA

#### 1. Results in Fixation Performed in the Recorded Presence of Established Wound Sepsis.

Code of Results	A	B	Bs	C	D	E	F	Total
Bone								
Femurs	9	3		1	2	2	4	21
Tibia-fibula			1	1			1	3 <sup>b</sup>
Humerus	1			1		1		3
Radius-ulna		1					1	2
	<hr/>	<hr/>	<hr/>	<hr/>	<hr/>	<hr/>	<hr/>	<hr/>
	10	4	1	3	2	3	6 <sup>a</sup>	29
	(35%)	(14%)	(3.5%)	(10.5%)	(7%)	(10.5%)	(21%)	(100%)

<sup>a</sup> The average time from wounding to fixation in this group was 36 days.

<sup>b</sup> This figure is probably too low.

2. *Recorded Associated Nerve Trunk Injury.*

Bone	No. of Fractures	No. of Nerve Injuries Recorded	Per Cent
Femur	135	9	6.6
Tibia-fibula	75	1*	1.3
Humerus	63	21	33.3
Radius-ulna	26	6	23.1

\* Nerve injuries in the leg often are not recorded, so this figure is probably too low.

3. There were *no deaths nor amputations* in these cases nor was either reported by the hospitals visited in a patient from M. T. O., or other theaters, upon whom a delayed internal fixation of a compound fracture had been performed.

4. *Refracture* occurred *seven* times, and in fractures of the femur only. The refractures were at points of bone loss from injury, not from sequestration except in one B result which is covered in footnote above. One additional case was a B result, the other five were A.

5. In every case, but two, from which metal was removed before wound healing, sequestra were found and removed.

## OBSERVATIONS UNSUPPORTED BY DATA

1. Knee motion was excellent in some of the fixed fractures of the upper half of the femur, but infrequently so in fractures of the lower third. Lower third and anterior wounds prejudice the return of knee motion. It is thought that the range of knee motion following rigid internal fixation, and following a program designed to achieve the maximum return, exceeds that which is seen in comparable cases managed by other measures. The fixations have not been followed always by a knee motion program. Failures to do so is by-passing one of the advantages of the method.

2. Wound healing without sequestration and without removal of the metal is favored by fixations through separate incisions particularly if the fixation is to be a plating.

3. Failure of wound healing has been prolonged in some cases because removal of sequestra and metal was delayed even though the fracture was well united.

4. Inadequate reduction of several fractures of the femoral shaft (Case 19) and of other long bones treated by nonfixation measures, with varying degrees of malunion and sometimes delayed union, were observed. The contour of many of these fractures on roentgenologic examination suggested that internal fixation would have been feasible, a procedure which, it is believed, would have improved the end-results. Nonunions of humeri with segmental defects were seen repeatedly in which union might have been achieved by maintaining bony apposition with metallic fixation (Case 20).

## CONCLUSIONS

1. There is a definite place for the use of delayed internal fixation in battle fractures in the fixed installations of the Communications Zone.

2. Its use should be as an adjuvant to fracture management under the principles previously expounded for reparative surgery of compound fractures, *i.e.*, excision of residual dead tissue including totally detached fragments, minimal periosteal stripping, closure of wounds to cover denuded cortex of bone with vascular soft parts, and dependent drainage of residual dead space. Failure to provide the measures which prevent sepsis and favor wound healing will prejudice the procedure.

3. The results achieved in this group of cases are deemed very satisfactory *with the exception of those in the plated fractures of the tibia and fibula and those associated with massive soft-tissue loss (Obligate-4)* particularly when they are evaluated in the light of their adjudged indications. Because no comparable data are available on similar groups of battle fractures managed without the use of delayed metallic fixation, it is impossible to establish a control with which to compare these results.

4. In the light of the results achieved in this series it seems reasonable to state that by the use of delayed internal fixation:

a. Nonunions in fractures with segmental defects or persistent distraction may be prevented in many cases, as is evidenced by the achievement of bony union in 27 (69%) of 39 cases in this series.

b. Varying degrees of malunion or, perhaps in some cases, delayed or nonunion, in fractures in which inadequate reduction was achieved by other measures, may be prevented in many cases, as is evidenced by the achievement of bony union in good apposition and alignment in 64 (85%) of 75 cases in this series.

c. Bony union in the optimal reduction of condylar fractures about the knee and elbow may be achieved, as is evidenced in 100% of 15 cases in this series.

d. The obvious advantages of well-stabilized maximum reduction of fractures which lend themselves to rigid stabilization and satisfactory wound healing may be achieved in many cases providing the fixation is performed by multiple screws with minimal periosteal stripping, as is evidenced by union in good position in 94 (98%), and wound healing without sequestration or removal of metal in 71 (74.7%), and in another 14 (14.9%) after their removal in a total of 95 cases.

If plating is the method of fixation bony union and satisfactory wound healing may be anticipated in a smaller percentage of cases, as is evidenced by union in 140 (84.3%), and wound healing without sequestration or removal of metal in 99 (59%), and *readily* in another 34 (20.3%) after their removal in a total of 168 cases.

e. Improved apposition of fragments may sometimes be provided by the use of wire loops, with anticipated favorable results in many cases, as is evidenced by the achievement of bony union in 59 (85.5%), and of wound healing without sequestration or removal of metal in 50 (72.5%), and in another 12 (17.4%) after their removal in a total of 69 cases regardless of other qualifying factors.

5. The hazard of delayed internal fixation appears to be increased sequestration, which may be explained by the periosteal stripping which the procedure entails and by its interference with readherence of soft parts to denuded bone. Other observations indicate that sequestration of bone in nonfixed battle fractures is limited practically always to bone that probably was denuded at wounding. Sequestration occurred in 34.3% of cases in this series, but, again, comparable data for a control are not available. From the estimated degree of sequestration observed in this series it seems reasonable to state that with:

a. Screw or wire fixation, sequestration is seldom massive, does not seem to interfere with union of the fracture, and probably would have occurred in many cases had nonfixation measures been employed.

b. Plating, followed by sequestration in 41% of 168 cases, is sometimes followed by massive sequestration and retardation of the attainment of full strength of the bone. It may create a massive defect reparable only by bone grafting.

6. a. Unless the fracture contour permits a rigid fixation by screws or unless wire loops appear advantageous, it is preferable to attempt reduction by traction or manipulation and strive for early wound healing. Following wound healing, fixation by plating or other fixation is relatively nonhazardous, as is evidenced by wound healing in 95% of 21 cases in this series without sequestration or removal of metal.

b. Fixations of the long bones of the upper extremity may be expected to give excellent results if the severity of bone loss or of the soft tissue injury does not prejudice the chances of union and wound healing. Of the seven F results (failures) in the upper extremity, five had massive soft-tissue loss and the other had bone loss.

c. Fixations of the femur performed on indications, utilizing multiple screws or wire loops and with minimal periosteal stripping may be expected to give excellent results. In the femur, there were no F results with screws, and the two F wire-loop fixations were bone loss cases, one of which had a massive soft-tissue loss. The hazard of periosteal stripping required for plating makes it preferable that plating be delayed until after wound healing unless the indications and anticipated advantages overshadow the hazard.

d. Fixations of the tibia by multiple screws or wire loops may be expected to give very satisfactory results. Periosteal stripping for the fixation should be minimized. Only the two Bs results—(heavy sequestration)—were unfavorable among those fixed by screws. The only unfavorable wire loop fixation (an F result) is only four months since wounding and is expected to unite. Plating of the tibia should be reserved until after wound healing. In the tibia, eight of the nine failures and six of the eight massive sequestrations were plate fixations. A greater use of wire loops to maintain approximation only may offer improved results.

e. The plating of the fibula in a fracture of both bones may be a useful procedure which is relatively nonhazardous. It maintains length and align-

ment, aids in achieving apposition of tibial fragments and provides some degree of immobilization of the fracture of the tibia.

7. Internal fixation as an adjuvant to the management of the unreduced septic compound battle fracture may aid in the control of sepsis and in achieving the maximum obtainable result (Cases 3, 4, 5 and 8). In 29 cases in this series bony union was achieved in *good alignment* in 20 (69 per cent), wound healing without further sequestration in 13 (45.5 per cent), and, after removal of sequestrums and metal, in 13 (17.5 per cent) additional.

8. The indications for delayed internal fixation can be defined only for those instances in the management of the wounded *when the advantages offered by maximum fracture reduction and (usually) stabilization are not overshadowed by other considerations*. With this qualification, it may be stated that the indications for the use of delayed internal fixation in the Base Hospital either at the initial operation of reparative surgery or later are\*:

A—Obligate:

- (1) Segmental defects or persistent distraction of fragments.
- (2) Inadequate reduction by other measures.
- (3) Displaced condylar fractures.
- (4) Associated nerve surgery which can be facilitated greatly by the fixation.

B—Desirable (Advantageous):

- (1) Fractures of the long bones (especially the femur) the contour of which permits rigid stabilization by multiple screws with minimum periosteal stripping.
- (2) Fractures in which nonrigid fixation by wire loops will provide a degree of fracture reduction probably not attainable without it.

9. Further study of this problem, and a comparable study of fractures managed by nonfixation measures, definitely are indicated. Each case should be evaluated in the light of the problem confronting the overseas surgeon and the anticipated result by fixation and nonfixation measures.

SUMMARY

Thus, a follow-up study of 332 compound fractures (all but 13 were missile fractures) which were fixed internally as an adjuvant to fracture man-

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\*In an evaluation of the indications, it must be understood that the principles of reparative surgery of compound fractures call for thorough wound visualization including the fracture site by gentle retraction of the wound edges at the initial operation of reparative surgery, usually five to ten days after wounding. Indicated excisional surgery is performed, the fracture site cleaned and visualized. It is then that the decision to use internal fixation is made in some instances, *e.g.*, loss of bone with segmental defect, displaced condylar fracture, oblique fracture of a shaft of bone which may be fixed in reduction with minimal additional periosteal stripping. In these cases, an additional anesthesia and operation are not required. An additional operation is necessary only in those cases where reduction by other measures has not been adequate or as an adjunct to nerve surgery.

agement in the Base Hospitals of the Mediterranean Theater of Operations reveals that in 258 (77.2 per cent) cases classed as A or B, the maximum achievable result has been obtained. The eight cases of fractures of the tibia in which sequestration was massive are not good results, but, in the end, an excellent weight-bearing extremity is anticipated. The 21 fractures classed as C results should become, after appropriate surgery, satisfactory end-results. Of the 14 nonunions, the E results, in only one was union retarded by the fixation, and that was an inferior technical job. The results in the 25 F's (or Failures) showed retardation in only 13 cases. Approximately 70 per cent of the fixations were performed at the initial operation of reparative surgery between five and 15 days after wounding, either through the compounding wound or a separate incision. The wounds were healed prior to the fixation in only 21 cases. The surgery was performed in 18 hospitals by approximately 50 surgeons of varying prewar civilian experience who had studied, and were experienced in the problems of wound and fracture management in reparative surgery of war wounds. From the conclusions which this study allows, the incidence of unfavorable results in a similar group managed under the same principles should be reduced to a minimum. A place for the delayed internal fixation of battle fractures has been established.

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*(To be continued in February issue)*

# THE INCIDENCE OF COMPLICATIONS IN THE USE OF TRANSFIXION PINS AND WIRES FOR SKELETAL TRACTION

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THE INCREASE in the number of severe fractures of the long bones during war provides an unusual opportunity for comparing the safety and reliability of various methods of fracture treatment. Recent personal communications from other Theaters of Operations and from the Zone of Interior indicate that enthusiasm for the use of transfixion pins and wires for skeletal traction has been considerably dampened by the high incidence of complications, principally osteomyelitis and chronic draining sinuses, which has followed their use. This has led some surgeons to prefer skin traction to skeletal traction, even though in many instances less satisfactory reduction and fixation of the fragments can be obtained. Some are even said to believe that the risk of infection in open operation is not appreciably greater than in skeletal traction.

At a General Hospital in India, 342 transfixion pins and wires (195 Kirschner wires, 95 Steinmann pins, and 52 Roger Anderson pins) have been used in treating fractures of the long bones during the past two years. Because of the experiences related by others, the complications encountered in using this method of fracture treatment at this hospital have been reviewed. In caring for a large number of Chinese patients, in whom treatment was necessarily carried to completion before disposition, we have had an opportunity, believed to be unusual in Army Hospitals overseas, to observe the majority of these pins and wires during the entire period of their use.

## TYPES OF FRACTURES AND METHODS OF TREATMENT

During the two-year period from April 1, 1943, to April 1, 1945, 342 transfixion pins and wires were used in the treatment of 233 fractures of the long bones. The fractures treated, the type and site of transfixion; the relative frequency of fixed and balanced traction; the average number of weeks of transfixion; the percentage receiving a prophylactic oral sulfonamide; and the complications are shown in Table I.

Complete fractures of the femoral shaft requiring reduction were routinely treated by balanced skeletal traction-suspension, with a Kirschner wire inserted through the tibia at the level of the tubercle or through the femur at the junction of the shaft and condyles. Transfixion pins or wires were used in treating fractures of the tibia, humerus, and forearm only in instances in which more conservative methods were inadequate for reducing the fracture or maintaining good position of the fragments.

All of the pins and wires were inserted at this hospital, using rigid aseptic



technic. In most instances, this procedure was carried out in the operating room. If it were avoidable, pins or wires were not inserted through an hematoma or within three or four inches of the wound of a compound fracture, even though insertion there would have been preferable for reduction of the fracture.

TABLE I

ANALYSIS OF THE USE OF 342 TRANSFIXION PINS AND WIRLS IN TREATING 233 FRACTURES OF THE LONG BONES

Fracture	Type of Transfixion			Site of Transfixion				Balanced Traction	Fixed Traction	Average Number of Weeks of Transfixion	Percentage Receiving Prophylactic Sulfonamide	Complications		
	Kirschner Wire	Steinmann Pin	Roger Anderson Pin	Olecranon	Distal Radius and Ulna	Femur	Tibia					Os Calcis	Infection	
Femur:														0
Comp.	120												Broken K. wire	1
Simp.	47	173	1	28		114	87	1	190	12	9.1	57.8	Loose K wire	3
Total	167												Yoke slipped	1
													Loose R.A. pins	2
Tibia:													Infection	1
Comp.	28													
Simp.	21	13	70				59	24	18	65	4.8	66.0	Transient peroneal palsy	2
Total	49													
Humerus:													Infection	0
Comp.	3													
Simp.	4	7			7				7		6.0	57.0	Loose wire	1
Total	7													
Forearm:													Infection	0
Comp.	15													
Simp.	5	2	24	24	23	27			14	36	6.8	66.0	Loose R.A. pin	1
Total	20													

Of the 342 pins and wires, 305 were observed during the entire period of their use and were removed at this hospital. In all but one the pin and wire holes healed promptly. The final result of only 37 transfixions is unknown. Seventeen of the pins and wires have not yet been removed and have not, during an average observation period of six weeks, shown any evidence of complications. The remaining 20 (Steinmann pins) were still incorporated in plaster when the patients were dispositioned to the Zone of Interior, and the final result cannot be stated, but no complication had been observed on disposition after an average period of 5.2 weeks.

#### COMPLICATIONS

Although there were no complications noted in the 37 transfixions in which the final result is unknown, this group has not been included in computing the incidence of complications. In the group of 305 transfixions in which the final result is known, complications occurred in 12, an incidence of 3.93 per cent. Four Kirschner wires became loose in bone, one wire broke,

# USE OF PINS AND WIRES FOR TRACTION

and in one instance the Kirschner bow slipped from one end of the wire, allowing traction to pull the wire out of the bone. Steinmann pins caused one infection and two transient peroneal nerve palsies, and three Roger Anderson pins became loose. The relative frequency of these complications is shown in Table II, with a brief descriptive comment about each.

TABLE II

ANALYSIS OF COMPLICATIONS OF 305 TRANSFIXIONS

Type of Transfixion	Complication	No.	Per Cent	Comment
Kirschner wire 186	Loose wire	4	2.15	Compound fracture femur. Wire through tibial tubercle became loose at 8 weeks. Probably due to too superficial insertion. Wire hole healed promptly. Not necessary to renew traction because of adequate bone union. Simple fracture femur. Wire through tibial tubercle pulled through into soft tissue at 6 weeks. Wounds healed promptly. Union sufficiently strong to permit discontinuance of traction. Simple fracture humerus in a psychotic patient. Constant manipulation of the yoke by the patient loosened the wire inserted through the olecranon within two weeks. Wire hole healed promptly on removal. Subsequent treatment with "hanging cast." Good result. Simple fracture femur. Wire through tibial tubercle became loose at 8 weeks. Probably due to too superficial insertion. Wire hole healed promptly. Not necessary to renew traction because of bone union.
	Broken wire	1	0.54	Compound fracture femur. Wire through distal femur broke at 14 weeks. Not necessary to renew traction because of adequate bone union. Wire hole healed promptly.
	Bow slipped	1	0.54	Compound fracture femur. Wire through distal femur slipped out of one end of bow and was pulled out of bone at 8 weeks. Not necessary to renew traction because of adequate bone union.
Steinmann pin 67	Infection	1	1.49	Simple fracture tibia transfixed with two Steinmann pins. Abscess about medial pin hole of distal pin at 4 weeks due to severe pyogenic folliculitis beneath encasement. Pin removed, abscess drained. Complete healing of wounds within 10 days. Healing of fracture not affected.
	Transient peroneal palsy	2	2.98	Compound fracture tibia. Partial peroneal palsy immediately following insertion of Steinmann pin through upper tibia. Due to faulty insertion, beginning on medial side. Palsy had disappeared before pins were removed at 6 weeks. Simple fracture tibia. Peroneal palsy discovered 2 weeks after insertion of pin in proximal tibia. Palsy had almost disappeared when pins were removed at 6 weeks.
Roger Anderson pin 52	Loose pin	3	5.77	Simple fracture radius and ulna. One pin found to be loose at completion of treatment, 10 weeks. Simple fracture femur. One pin found to be loose at completion of treatment, 10 weeks. Simple fracture femur. One pin found to be loose at completion of treatment, 10 weeks.

In 11 of these instances the complications were probably avoidable. Four loose Kirschner wires and three loose Roger Anderson pins were apparently due to improper insertion—too superficial insertion in the case of the Kirschner wires, and failure to engage both cortices in the case of the Roger Anderson pins; or to excessive manipulation of the traction apparatus by the patient in certain Chinese and in one psychotic patient. It may be assumed that the wire which broke and the bow which slipped were defective. The two peroneal nerve palsies, resulting from the insertion of Steinmann pins

through the upper tibia, were due to the faulty technic of beginning the insertion on the medial surface. If landmarks are carefully palpated and insertion is begun on the lateral surface, the tibia may readily be transfixated at an adequate depth without endangering the peroneal nerve. Insertion begun on the medial surface may injure the nerve if the point of insertion is too far posterior or there is posterior deviation of the pin.

A small amount of drainage from the pin or wire holes, at some time during the course of transfixion or for one or two days following removal, has not been uncommon. Not infrequently the drainage has appeared grossly to be purulent but, because of the absence of local and general signs of inflammation and the prompt healing following removal of the pins or wires, this has not been regarded as infection. Infection occurred in only one instance about a Steinmann pin inserted through the lower tibia, and probably could not have been avoided. Severe pyogenic folliculitis due to occlusion by the plaster encasement (which in our experience has been infrequent) developed, and was almost certainly the source of the infection. Following incision and drainage of an abscess which formed about the medial entrance of the pin four weeks after insertion, the drainage incisions and the pin holes healed within ten days and, at present, four weeks later, no evidence of renewed inflammation or drainage has appeared. There has been no roentgenographic evidence of osteomyelitis about the pin hole. Since this infection occurred just prior to the time planned for removal of the pins, when adequate callus was present, the course of treatment was not altered.

It is to be noted in Table II that in this single instance of infection, and in the 11 other instances in which complications occurred, the course of treatment and the final result were not significantly affected.

Prophylactic oral sulfonamides were administered in approximately 60 per cent of the patients, either because the fracture was compound or because of associated injury or disease. No infection occurred in the group. Since only one infection occurred in the 40 per cent not receiving sulfonamides, and it is not at all certain that a sulfonamide would have prevented this infection, there is no statistical evidence that prophylactic sulfonamides played a part in preventing infection at the pin site in this series. In no instance was a prophylactic sulfonamide used for the sole purpose of preventing infection at the pin site.

#### SUMMARY

1. Three hundred and forty-two pins and wires were used to transfix bone for skeletal traction in the treatment of 233 fractures of the long bones.
2. In the 305 transfixions in which the final result is known complications occurred in 12, an incidence of 3.93 per cent.
3. Infection at the pin site occurred once, an incidence of 0.33 per cent. This infection is believed to have been unavoidable. Osteomyelitis and a chronic draining sinus did not result.

4. Other complications, all of which are considered avoidable, were:
  - a. Loosening of four Kirschner wires.
  - b. Loosening of three Roger Anderson pins.
  - c. Two transient peroneal nerve palsies.
  - d. Breaking of one Kirschner wire.
  - e. Slipping of one Kirschner wire bow.
5. In no case did a complication have any significant effect upon the course of treatment or the final result.

#### CONCLUSION

In our experience the use of transfixion pins and wires for skeletal traction has been a safe and reliable procedure. Complications have been infrequent and benign.

# ABDOMINAL SURGERY IN AN EVACUATION HOSPITAL

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THE SEPARATE EVACUATION HOSPITALS in the European Theater of Operations have had a varying relationship to front line activity made necessary, first, by the small area which the American Forces held early in the Normandy Campaign, and, later, by the rapid drive of the Armies from Normandy across France and Belgium to the German border. The location of our own hospital unit has varied from four to 30 miles behind the active fighting front. During certain periods we functioned forward of the Field Hospitals and Clearing Companies, but for the most part we were situated behind these units. The type of cases we received varied with our location. During the long periods when we were a well-advanced installation forward of the Field Hospitals we received a larger percentage of patients with abdominal injuries. These patients, classified as nontransportable, otherwise might not have reached our hospital.

From the middle of June, 1944, to the end of December, 1944, five per cent of the total battle casualties received had abdominal injuries. This series of 341 patients includes all those with penetrating and perforating wounds involving the peritoneum. In addition, we have included those cases of severe retroperitoneal hemorrhage from injuries to the large vessels, such as the vena cava, and from injury to the kidneys, because such cases frequently necessitated exploratory celiotomy to determine the full extent of the injury. Also included in the series is a group of cases of perforating wounds of the rectum. All of these cases had inguinal colostomy performed as part of their treatment. We have excluded from our series all those cases which had been operated upon prior to their admission to our own hospital.

For clarification we have established the following classification: First, combined thoraco-abdominal wounds involving perforation of the diaphragm and due to a single missile. Second, combined thoraco-abdominal wounds due to two or more missiles and not involving perforation of the diaphragm. Third, abdominal wounds not associated with chest injuries (Table I).

We believe this series of abdominal war injuries is the largest which has thus far been presented by a single hospital unit. On the basis of this experience, there are certain facts which we can present and other clear-cut impressions which we can offer.

The diagnosis of intra-abdominal perforation is usually obvious in most battle casualties. However, when the location of the entrance and exit wounds are far removed from the abdominal area the diagnosis may be very difficult. The diagnosis of intra-abdominal injury should be determined by

history, physical examination, and roentgenologic examination. Some patients show no abdominal rigidity and little abdominal tenderness, especially those patients in shock or impending shock. These patients may have physical signs of peritoneal irritation only after they have recovered from the shock state. Patients with small perforations of the descending and sigmoid colons occasionally show signs of peritoneal irritation late. Shoulder pain is not an outstanding symptom. Auscultation of the abdomen will usually reveal a silent abdomen when peritoneal irritation is present. Absence of liver dullness is often present but is not a constant finding in gastro-intestinal perforations. The location of the foreign body roentgenologically may determine the diagnosis. Proctoscopy and sigmoidoscopy have been invaluable in uncovering perforating wounds of the rectum and sigmoid colon. A total of 305 patients with buttock, perineal, or upper thigh wounds were proctoscoped and sigmoidoscoped. Perforations of the lower colon and rectum were visualized in 34 cases. Catheterization and uranalysis may be the determining factors in exposing wounds of the urinary tract. Uanalysis is carried out in all suspected abdominal injuries. Aspiration of gastric contents through a Levin tube may reveal evidence of injury to the stomach. In some cases only exploration of the wound or celiotomy will reveal the intra-abdominal injuries.

The preoperative management of the battle casualty with intra-abdominal injury may be the decisive factor in the ultimate outcome. All battle casualties suspected of having intra-abdominal injuries were sent directly to a special shock ward for examination and observation even though there was no evidence of shock at the time of admission to the hospital. The absence of shock in patients even with severe abdominal wounds is not an unusual finding.

Complete physical examination of the patient should be accomplished before intravenous therapy is instituted. Treatment for shock is immediately instituted with transfusions of whole blood and plasma in an effort to increase the blood pressure, improve the general condition of the patient, and to prepare for operation. In patients in whom active intra-abdominal bleeding is suspected operation is performed immediately and the blood transfusion is continued during the operation.

It has been our experience that whole blood rather than plasma should be used in combating the severe shock due to intra-abdominal injuries. It usually requires one or more liters of whole blood to bring the patient out of the shock state and to satisfactory condition for operation. Most patients will show definite response to this therapy within one to two hours unless active bleeding persists or the state of "irreversible shock" is present. The general appearance of the patient and the skin warmth are valuable criteria of response to therapy. Repeated blood pressure readings are important but any single reading in itself may be misleading. Dehydration in a patient should be treated by intravenous isotonic dextrose solutions. Plasma itself has only very limited use in the preoperative management of patients with abdominal injuries.

Patients with evisceration of the intra-abdominal organs require early surgery. These patients are usually in moderate or severe shock and do not respond to the usual forms of shock therapy. It is only when the eviscerated organs are replaced by operation that these patients show improvement. In our series of cases, we have had 16 patients with evisceration. Ten of these (63.8 per cent) died. Three of those who recovered had evisceration of omentum only. Excluding these the mortality rate was 76.9 per cent. Patients with herniation of viscera through a wound in the diaphragm also require urgent surgery since they do not respond to shock therapy until the operative repair has been accomplished.

TABLE I

## TABULATION OF ABDOMINAL INJURIES

A. PATIENTS WITH COMBINED THORACIC AND ABDOMINAL INJURIES CAUSED BY A SINGLE MISSILE. ALL OF THESE PATIENTS HAD PERFORATING WOUNDS OF DIAPHRAGM AND PLEURA

Type of Case	No of Cases	Deaths	Operated	Died Without Operation	Operative Mortality %	Over-All Mortality %
Esophagus.....	(a) 2	0	2	0	0	0
Stomach.....	3	(b) 2	2	1	50.	66.6
Stomach, small intestine & liver.....	1	1	0	1	0	100.
Stomach, transverse colon, spleen, with evisceration.....	2	(c) 2	1	1	100.	100.
Stomach, transverse colon and liver..	2	2	2	0	100.	100.
Stomach, transverse colon and small intestine.....	1	1	1	0	100.	100.
Stomach, descending colon and liver.	1	1	1	0	100.	100.
Stomach, liver and spleen.....	4	3	3	1	66.	75.
Small intestine.....	1	0	1	0	0	0
Small intestine, descending colon and kidney.....	1	0	1	0	0	0
Transverse ascending colon and liver	1	1	1	0	100.	100.
Transverse colon.....	1	0	1	0	0	0
Transverse colon and spleen.....	1	0	1	0	0	0
Descending colon.....	1	1	0	1	0	100.
Omentum, evisceration of small bowel	1	1	1	0	100.	100.
Peritoneum.....	11	(d) 3	11	0	27.3	27.3
Spleen.....	13	2	12	1	8.3	15.4
Liver.....	23	(e) 3	23	0	13.0	13.0
Liver and gallbladder.....	1	0	1	0	0	0
Liver and kidney.....	4	4	2	2	100.	100.
Kidney, with herniation into pleural space.....	1	1	1	0	100.	100.
Stomach and spleen.....	4	1	4	0	25.	25.
Stomach and liver.....	2	1	2	0	50.	50.
Total.....	82	30	74	8	29.7	36.6

B. PATIENTS WITH CHEST AND ABDOMINAL INJURIES CAUSED BY MULTIPLE MISSILES. THESE PATIENTS HAD HEMOTHORAX, BUT NO WOUND OF DIAPHRAGM

Small intestine.....	1	1	0	1	0	100.
Small intestine and descending colon.	1	0	1	0	0	0
Transverse colon.....	1	0	1	0	0	0
Ascending colon and kidney.....	1	1	1	0	100.	100.
Retroperitoneal space.....	1	1	1	0	100.	100.
Kidney.....	1	0	1	0	0	0
Perineum and genitalia, with colostomy and suprapubic cystotomy....	1	0	1	0	0	0
Transverse colon, descending colon and kidney.....	1	1	1	0	100.	100.
Total.....	8	4	7	1	42.8	50.
A & B totals.....	90	34	81	9	30.9	37.8

# ABDOMINAL SURGERY IN ADVANCED ZONE

TABLE I (Continued)  
TABULATION OF ABDOMINAL INJURIES

Type of Case	No. of Cases	Deaths	Operated	Died Without Operation	Operative Mortality %	Over-All Mortality %
C. ABDOMINAL INJURIES NOT COMPLICATED BY CHEST INJURIES						
Stomach.....	3	1	2	1	0	33.3
Stomach, duodenum and liver.....	1	0	1	0	0	0
Stomach, duodenum and transverse colon.....	1	0	1	0	0	0
Stomach, duodenum and small intestine.....	1	0	1	0	0	0
Stomach, small intestine and transverse colon.....	1	0	1	0	0	0
Stomach and transverse colon.....	1	0	1	0	0	0
Stomach, small intestine, transverse colon and liver.....	1	1	1	0	100.	100.
Stomach, liver, kidney and pancreas.....	1	1	1	0	100.	100.
Duodenum.....	1	0	1	0	0	0
Duodenum, small intestine.....	1	0	1	0	0	0
Duodenum and descending colon....	1	1	1	0	100.	100.
Small intestine.....	39	(f-s) 8	37	2	16.2	20.5
Small intestine and ascending colon..	7	5	(g) 5	(h) 2	60.	71.4
Small intestine, ascending and descending colon.....	4	2	(i) 3	(j) 1	33.3	50.
Small intestine and transverse colon.	6	(g) 4	6	0	66.6	66.6
Small intestine and descending colon	13	4	10	3	10.	30.8
Stomach, spleen.....	1	0	1	0	0	0
Small intestine, transverse colon and spleen.....	1	0	1	0	0	0
Small intestine, descending colon, rectum and urinary bladder.....	5	4	5	0	80.	80.
Small intestine, extraperitoneal rectum.....	4	0	4	0	0	0
Ascending colon.....	11	1	11	0	8.3	8.3
Ascending colon and liver.....	1	0	1	0	0	0
Transverse colon.....	2	0	2	0	0	0
Transverse colon, small intestine, liver, evisceration.....	1	1	1	0	100.	100.
Transverse colon and liver.....	1	0	1	0	0	0
Descending colon.....	19	(l) 5	19	0	26.3	26.3
Descending colon, liver.....	2	1	1	1	0	50.
Descending colon, bladder.....	1	0	1	0	0	0
Descending colon, kidney.....	1	0	1	0	0	0
Extraperitoneal rectum.....	23	(m) 1	23	0	4.3	4.3
Extraperitoneal rectum and urinary bladder.....	1	0	1	0	0	0
Gallbladder.....	1	0	1	0	0	0
Gallbladder, liver and kidney.....	1	0	1	0	0	0
Spleen.....	5	0	5	0	0	0
Liver.....	8	2	5	1	20.	25.
Liver and kidney.....	4	0	4	0	0	0
Liver and small intestine.....	2	0	2	0	0	0
Retroperitoneal space, with hemorrhage.....	16	(e) 3	14	2	7.1	18.1
Mesentery, omentum.....	8	1	7	1	0	12.5
Peritoneum.....	14	(r) 1	12	0	8.3	7.1
Peritoneum, kidney.....	1	1	1	0	100.	100.
Kidney.....	7	3	(e) 6	1	33.3	42.9
Urinary bladder.....	4	1	4	0	25.	25.
Perineum and cystotomy.....	2	0	2	0	0	0



TABLE I (Continued)  
TABULATION OF ABDOMINAL INJURIES

Type of Case	No. of Cases	Deaths	Operated	Died Without Operation	Operative Mortality %	Over-All Mortality %
Blast injury, with gangrene.....	2	(p) 1	2	0	50.	50.
Exact diagnosis unknown.....	(q) 1	1	0	1	0	100.
Subtotal.....	232	54	212	16	17.9	23.3
Negative explorations.....	19	0	19	0	0	0
Total.....	251	54	231	16	16.4	21.5
Grand total.....	341	88	312	25	20.2	25.5

NOTE: Twenty-five patients died without operation. The length of time they were in the hospital varied from 5 minutes to 12 days. The patient that died after 12 days was admitted with diffuse peritonitis and a traumatic ileostomy. He was treated expectantly. One patient died after 40 hours, who had fulminating peritonitis on admission. Eighteen, or 72% of these patient were in the hospital 5 hours, or less; 13, or 52%, 4 hours, or less; 11, or 44%, 3 hours, or less; 10, or 40%, 2 hours, or less; and 7, or 28%, one hour, or less.

(a) One also had a wound of the spleen.

(b) Also had brain injury.

(c) One had a severed renal artery and vein.

(d) Had large diaphragmatic hernia.

(e) One also had a perforated vena cava.

(f) The two that were not operated upon had peritonitis on admission, and one had a severed inferior mesenteric artery. Two that were operated upon had eviscerations. One had a perforated vena cava plus evisceration.

(g) One also had a severed external iliac artery.

(h) One had a severed ileocolic artery. One had evisceration six hours old.

(i) One also had evisceration seven hours old.

(j) Also had FCC femur.

(l) Two had severed internal iliac arteries.

(m) Had gas gangrene infection; also brain injury.

(o) One had a perforated vena cava, one had a severed internal iliac artery, one had a severed common iliac artery.

(p) Also had traumatic amputation both thighs.

(q) Patient was a Belgian civilian; no autopsy done.

(r) Died with pulmonary embolism. Had associated extremity wounds.

(s) One also had traumatic amputation of left arm; died with hypostatic pneumonia, age 78. One also had a fractured pelvis; died with bronchopneumonia, age 80. One also had traumatic amputation of leg and multiple less severe injuries.

Our experience has shown that the time interval before operation is not the most important factor in determining mortality rates unless there is evidence of continued internal bleeding or evisceration. We have had good results with some patients operated on over 36 hours after injury. Our policy has been to restore these patients to the best possible condition prior to operation regardless of the length of time that has elapsed between the time of injury and the time of admission. Usually a patient with a blood pressure of below 80 systolic will not tolerate major surgery. However, we have seen some patients who despite the usually adequate shock therapy, do not respond by increased blood pressure. We feel that these patients, too, deserve the benefit of surgery even though the prognosis is not hopeful for their surviving the operative procedure. Of our 63 post-operative deaths, 17 occurred during the operative procedure. Had we not attempted operation these patients would surely have died but would have

been considered nonoperative deaths. However, we have had a number of similar cases who appeared as hopeless operative risks but did survive major operative procedure to go on to recovery. It is this group of patients that has made worth while the undertaking of surgery in the bad risk cases. We have had 25 other patients who died without surgery having been performed. Most of these were admitted in a moribund state and died within a few minutes to a few hours after admission.

The following case report illustrates the type of bad risk patient in whom the final result was successful:

**Case 1.**—A soldier wounded 0300, July 28, was admitted to the hospital at 0500, same date. He had a penetrating wound of the left chest due to a bomb fragment. He was in profound shock, dyspnea was marked, and pain was very severe. There was external bleeding from the wound, and physical examination suggested the presence of a left hemothorax. Roentgenologic examination disclosed the presence of fluid in the left chest and also a bomb fragment in the abdominal cavity.

One thousand cubic centimeters of whole blood was given. The blood pressure failed to rise above systolic 64, diastolic 40. Because the patient showed evidence of continued bleeding he was prepared for immediate operation. Under intratracheal positive pressure anesthesia of nitrous oxide, oxygen and ether, open thoracotomy was performed. The chest cavity was found to contain omentum, and transverse colon, the latter almost completely transected and fecal contents free in the pleural space. A severely lacerated spleen, bleeding actively, was also present in the chest cavity. The left lower lobe of the lung was found to be lacerated.

The operative procedure consisted of suture of the laceration in the lung, splenectomy, and repair of the multiple lacerations in the diaphragm. Closed system catheter drainage was provided. The abdominal cavity was then explored through a midline incision and all blood was aspirated from the peritoneal cavity. The severed ends of the transverse colon were brought out through a stab wound as a colostomy. The abdomen was closed without drainage.

The patient was given 1,000 cc. of whole blood during the operation during which his general condition remained unchanged. Postoperative therapy included an additional 1,500 cc. of whole blood and continuous intranasal oxygen. Wangenstein drainage was instituted and continued for three days. He was given 40,000 units of penicillin every four hours and sulfadiazine to maintain a blood level of between 8 and 12 mg. per 100 cc. A total of 25 Gm. of sulfadiazine and 840,000 units of penicillin were given.

The patient had a mild postoperative course. The highest temperature postoperatively was 100.6° F., pulse 130. Drainage from the catheter in the pleural space was considerable. The catheter was removed on the third day. Hematuria was present for the first few days but cleared. On the seventh day 800 cc. of straw-colored fluid was aspirated from the left pleural cavity. The patient's progress had been very satisfactory, and he was evacuated to a rear hospital on the ninth postoperative day.\*

Chart I shows that the time factor between injury and operation has a definite bearing on the mortality rate. The mortality rate for patients operated on within six hours was 30 per cent. This dropped in the subsequent six-hour periods to reach 10 per cent at the 24- to 30-hour period. This can be explained by the fact that the most desperate cases, those in shock resulting

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\* All abdominal cases are held in this hospital for a minimum of ten days. This particular patient was transferred to another nearby Evacuation Hospital on the ninth postoperative day because the military situation necessitated moving this hospital.

from active hemorrhage, were operated upon in the first six-hour period. The mortality rates after the 30-hour period may be misleading since they are based on a very small number of cases operated upon during that period.

We do not advise delay in operation for these cases. We do believe, however, that sufficient time be taken to prepare patients more adequately for operation. Those patients who begin to respond to the shock therapy are

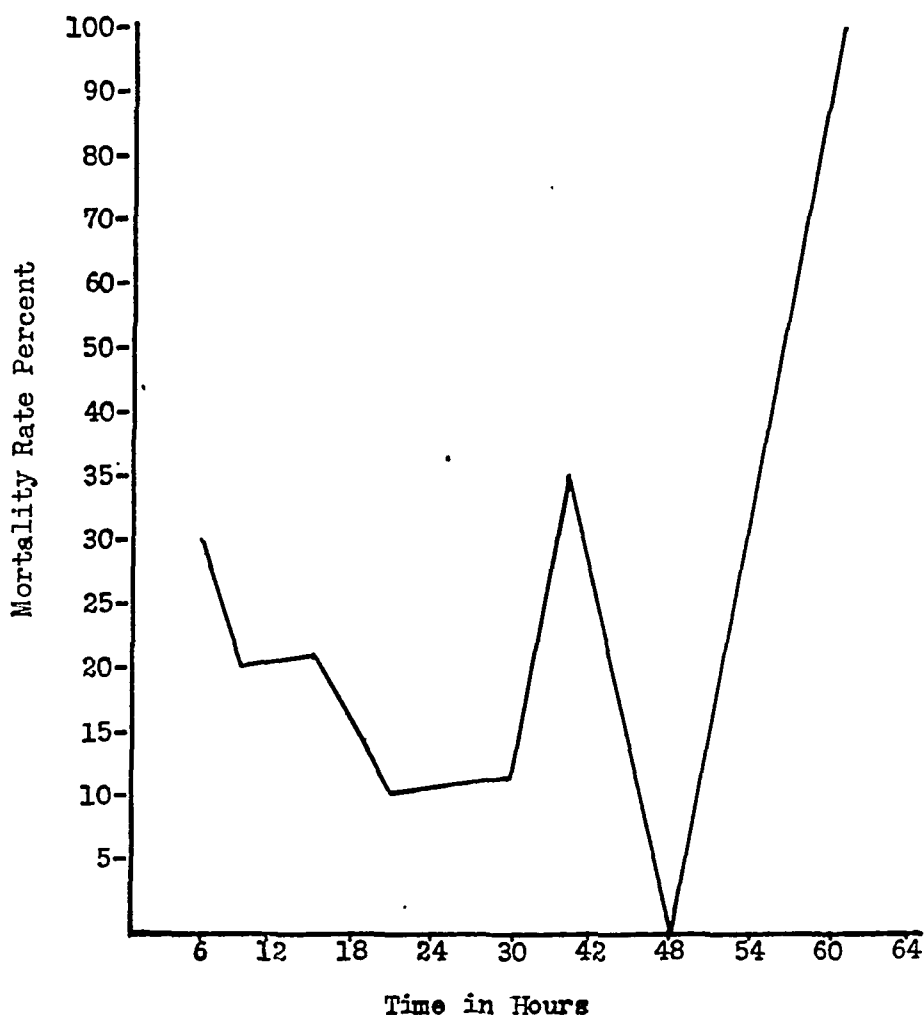


CHART I  
OPERATIVE MORTALITY RATE IN RELATION TO TIME-LAG FOLLOWING INJURY

probably better risks if given a few additional hours to improve and stabilize their general condition. Early in the campaign we were enthusiastic regarding early surgery in these cases. This enthusiasm has diminished with experience. It is our impression that the use of chemotherapy has made possible the good results in some of these late cases.

There is a large percentage of patients with intra-abdominal injuries who, in addition, have other major injuries. We have had 81 cases with combined chest and abdominal injuries, ten cases with combined head and abdominal injuries, and seven cases with abdominal injuries combined with traumatic

amputations of an extremity. Patients with compound fractures of one or more of the long bones as associated injuries are not infrequent. Each patient with multiple major injuries presents a separate problem in surgical management. The separate injuries may each require a major operative procedure. Because of the condition of the patient it may be necessary to perform these operations successively or on different days. Multiple major operations performed at the same time by several surgical teams may throw the patient into irreversible shock. The following patient demonstrates the type of battle casualty upon whom multiple operations had to be performed successively and on different days:

**Case 2.**—A soldier wounded 2300 hours, September 29, was admitted 0800, September 30. Patient had sustained multiple severe wounds of head, chest, abdomen, left arm and left foot due to shell fragments. He was unconscious on admission. His blood pressure was elevated, being systolic 150, diastolic 80. There was questionable viability of the left foot. The patient was treated with blood, plasma, glucose and saline solution and sedatives. His response was slow and operative procedure had to be delayed until October 1, 36 hours after injury. On this date, under endotracheal anesthesia of nitrous oxide, oxygen and ether, débridement of the chest wound and open thoracotomy were performed. Two hundred cubic centimeters of blood was aspirated from the pleural space and a long laceration of the diaphragm was sutured. Tight closure of the chest was accomplished. Exploratory celiotomy disclosed no intra-abdominal injury. The foreign body was not recovered. Penicillin and sulfanilamide powder was applied to the various wounds and further surgery postponed.

The patient had a moderate postoperative reaction, pulse 110 to 140, blood pressure rose from 88/50 to 124/60. He was given several transfusions of blood and plasma. He continued to be drowsy but could be aroused. He was incoherent.

On October 2, under local anesthesia, a large lacerated wound of the scalp was excised and a fracture of the outer table of the skull was exposed. Closure of the scalp wound was accomplished. The patient was conscious but disoriented during operation. On October 3 the patient was clearer mentally. The wound of the left arm was exposed and 40,000 units of penicillin and sulfanilamide powder instilled into the wound. The traction splint was maintained. On October 4 the patient was conscious and rational. The slight facial weakness noted originally persisted. His fundi showed bilateral blurring of the disks. The spinal fluid was under normal pressure.

On October 8, because of circulatory failure in the left foot resulting from the original trauma, a guillotine amputation of the lower third of the left leg was performed under pentothal anesthesia. The patient's general condition improved considerably. His sensorium was clear. His temperature was normal and his pulse varied between 80 and 120. On October 13 a plaster encasement was applied to the left arm to control the fracture of the humerus, and the patient was prepared for evacuation to a Rear Hospital.

We have found that a certain small group of cases could be treated without abdominal exploration. This includes patients with retroperitoneal hemorrhage in whom the active bleeding has stopped and who have recovered from the shock state. A few cases with perforating wounds high in the right upper quadrant of the abdomen, even with a foreign body present in the liver, also responded well to nonoperative treatment. Patients with generalized blast injury should also have expectant treatment as a general rule. All these patients should, of course, have adequate débridement and drainage of their

wounds. However, in cases of questionable intra-abdominal injury, exploratory celiotomy should be carried out. We have performed 19 exploratory celiotomies in which no intra-abdominal injury was present. There were no deaths.

Inhalation anesthesia by nitrous oxide, oxygen, and ether in a closed system, preferably with intratracheal intubation, has been our anesthetic of choice. This form of anesthesia is imperative in combined thoraco-abdominal injuries since it allows for positive pressure. Open-drop ether has its particular use in patients in severe shock from internal hemorrhage. Spinal anesthesia has no place in abdominal surgery of battle casualties. Pentothal is not a satisfactory anesthetic in this type of case and should not be used. Regional anesthesia by using intercostal nerve block was used in three cases where a general anesthetic would have been too great a burden for the patient. *It is unnecessary to infiltrate novocaine in the abdominal wall with intercostal nerve block.* These were cases of severe shock associated with hemorrhage. Local infiltration and regional block are valuable in patients with additional extensive face or blast injury which precludes the use of any inhalant anesthetic. The following patient demonstrates the extensive surgical procedures which were carried out under regional anesthesia:

**Case 3.**—A Belgian female, age 30, wounded by artillery shell fragment, 1200 hours, November 15, was admitted to this hospital 1500 hours, November 15. The patient was in profound shock. Examination revealed a penetrating wound of the right upper quadrant of the abdomen and a laceration of the right forehead. The blood pressure was 90/60, and pulse 140. There was generalized abdominal tenderness and rigidity, but these were more marked in the right upper quadrant. The urine was grossly bloody. She was given blood and plasma preoperatively without any marked response. A diagnosis of continuing intra-abdominal bleeding was made, and operation was performed. Under bilateral block of the seventh to eleventh intercostal nerves with 60 cc. of 1 per cent procaine hydrochloride supplemented with 0.37 Gm. of sodium pentothal intravenously, exploratory celiotomy was carried out. The patient was found to have a severed cystic artery, perforating wounds of the gallbladder, kidney and liver. The cystic artery was ligated, the gallbladder was removed, the liver wound was packed and the kidney wound was sutured. She was given 1,500 cc. of whole blood and 1,500 cc. of Alsever's solution during the operation. The postoperative course was stormy for the first seven days, after which her improvement was rapid, and she was evacuated on the 12th postoperative day in good condition.

In combined chest and abdominal injuries we have found it preferable to do the chest surgery before the abdominal surgery is performed. It is important to stabilize the respiratory exchange, reduce the shock, and give the patient maximum help to withstand the additional hazard of the anesthetic.

The common intrathoracic procedures were aspiration of an hemothorax, removal of a foreign body or imbedded rib fragments from the lung, and suture of a lacerated diaphragm. In large penetrating thoraco-abdominal wounds, the transthoracic approach to the diaphragm has been most useful, and suture of the diaphragm is relatively easy. Splenectomy and suture of

the stomach through the thoracic approach can be readily performed. Even suture of the small intestine becomes feasible if the opening in the diaphragm is enlarged sufficiently.

For surgical exploration of the abdominal cavity adequate exposure is essential to visualize all parts. This may involve the use of long abdominal incisions, but these generally heal well. The proper location of the incision over that part of the abdomen most involved will facilitate the intra-abdominal operative procedure and shorten the operative time. Paramedian incisions with separation of either of the recti muscles were used most frequently. Exposure through subcostal incisions proved very useful especially in cases with injuries to the stomach, liver and spleen, and the hepatic and splenic flexures of the colon. Anticipation of the necessity for colostomy may alter the site of the incision.

It is important to make a systematic examination of the abdominal contents. Injuries were frequently multiple and were often far removed from one another. The entire small intestine should be examined serially before individual perforations are sutured. Even when perforations are multiple in adjacent areas suture of the separate perforations is preferable to resection. There is no need for excision of the mucosa. We have sutured as many as 16 individual perforations in one short segment of the small bowel. One must be especially careful not to overlook perforations. Autopsies disclosed that in six cases single perforations had been overlooked at the original operation. There were four such cases involving the small bowel, one the stomach and one the cecum. Resection of a portion of the small intestine is indicated when the mesentery is detached over a length greater than two inches. End-to-end anastomosis is the procedure of choice because of its simplicity and time-saving value. Enterostomy of the small intestine should not be done.

Small wounds of the cecum and the ascending colon may be sutured and a large Pezzar catheter placed in the cecum as a safety valve. In wounds of the transverse colon, descending colon and sigmoid we have used the Mikulicz or loop-type of colostomy. It has been pointed out by the surgeons who do the secondary closure that the loop-type is preferable. The involved loop with the colostomy opening should be brought out through a separate incision rather than through the original operative incision. This separate incision is most important since it obviates severe infection and wound disruption which frequently occur when the damaged bowel segment is brought out through the original operative incision. The exteriorized loop must be free of tension.

Thirty-four patients had rectal perforations and, of these, six were intraperitoneal and 28 extraperitoneal. Intraperitoneal perforations should be sutured and an inguinal sigmoidostomy performed to divert the fecal stream. In extraperitoneal rectal wounds adequate drainage is most important and this may necessitate removal of the coccyx. Drainage through the gluteal muscles should be avoided when possible. In all rectal wounds, whether

intraperitoneal or extraperitoneal, a proximal colostomy should be performed to prevent further soiling and to allow for healing of the injured part.

We are impressed with the large number of patients who had hemoperitoneum with large quantities of both clotted and unclotted blood. In a great percentage of the cases the source of the hemorrhage was found to be the spleen. We had 26 cases of severe laceration of the spleen. In extensive lacerations or severe bleeding from this organ splenectomy is indicated. There were a few cases with very superficial lacerations which did not require suture. There were no cases of secondary hemorrhage. Most of these cases had associated major injuries and splenectomy would have increased the hazard of operation. In some patients splenectomy was performed to allow more adequate exposure for suture of a lacerated diaphragm.

Transfusion with whole blood and plasma during the operative procedure is especially important even though large quantities may have been used in the preoperative management. We have noted that there were no transfusion reactions while patients were under general anesthesia. This observation is worthy of further investigation.

Liver wounds are best managed by packing, or by use of a free muscle graft. Recently cellulose-acetate gauze (absorbable) has been made available to Army units for hemostasis in liver and kidney wounds. To date we have had no experience with the use of this material. Drainage should always be established below the level of the diaphragm. The diaphragm should be closed securely in right thoraco-abdominal injuries associated with liver wounds. Interrupted fine silk sutures are used to close each leaf of the diaphragm. In most of these cases the foreign body was in the substance of the liver and was not removed. Unless the diaphragm is closed and adequate drainage instituted a biliary-pleural fistula, liver abscess, or sub-diaphragmatic abscess may result.

All abdominal incisions should be closed carefully in layers and reinforced with silk or wire retention sutures down to the peritoneum. These sutures should be evenly spaced and in sufficient number. They should be tied very loosely to prevent necrosis of the intervening tissue. Drainage of the peritoneal cavity is not necessary except in wounds of the liver. These drains are left in for ten days.

There were no special problems in the postoperative period of our patients. Intestinal obstruction in the early postoperative period, even after extensive surgical procedures, was rare. The routine use of intravenous fluids, at least 3,000 cc. daily, maintained hydration. Wangenstein drainage was used routinely on all postoperative abdominal cases, and was most important in preventing postoperative distention. The Miller-Abbott tube was found useful in several patients, and the usual difficulty in its passage was minimized by the use of mercury in the bulb. The use of prostigmine prophylactically in the immediate postoperative period showed good results in several cases.

Our postoperative routine included the intramuscular injection of 20,000 units of penicillin every four hours for at least 18 doses. The value of

penicillin in preventing postoperative pulmonary complications can readily be shown by the small number of such complications in this large series. We had an incidence of 1.6 per cent. Postoperative wound infection was rare, and this is attributed to the use of penicillin and the sulfa drugs. Our postoperative routine also included the use of vitamins. These were given orally when possible or intravenously when necessary. The routine dose was 1,000 mg. of ascorbic acid and 20 mg. of thiamine hydrochloride daily. Adequate blood protein levels were maintained by the liberal use of plasma and whole blood was used to increase the red cell count and hemoglobin levels.

#### SUMMARY

1. A series of 341 patients with abdominal war wounds is presented. This includes 81 patients with combined thoraco-abdominal wounds. Surgery was performed on 312 patients. Many of these patients had additional major injuries. The operative mortality was 20.2 per cent. Eight per cent of the patients died without surgery having been performed.

2. The methods used in making the diagnosis of intra-abdominal injury including the importance of proctoscopic and sigmoidoscopic examinations are discussed.

3. The importance of adequate preoperative treatment as a determining factor in the final result is stressed.

4. The decrease in mortality rate on patients operated upon six to 30 hours after injury is explained in part by the fact that the worst cases are operated upon during the first six-hour period. Delayed operation is not advocated but rather the effort to prepare the patient adequately for operation is stressed.

5. The importance of early surgery in patients with evisceration of abdominal organs is noted. These patients do not respond to the usual forms of shock therapy until surgical replacement of the evisceration is accomplished.

6. Certain surgical procedures that we have employed in the operative management of the various types of injuries encountered are presented.

7. The importance of adequate and well-placed incisions, of systematic and thorough abdominal exploration, and careful abdominal closure is discussed.

8. The necessity for careful closure of the diaphragm and institution of subdiaphragmatic drainage in right-sided thoraco-abdominal wounds is emphasized.

9. The value of intensive postoperative treatment, including the use of penicillin and the sulfa drugs, is shown by the low incidence of postoperative complications.

10. Case histories of selected cases are presented in detail.

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# CHEMOTHERAPY IN TRAUMATIC SURGERY OF THE ABDOMEN

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THE TRUE EFFICACY of the sulfonamides and penicillin in the treatment and prevention of intraperitoneal infection is yet to be determined. It is our impression that they have been highly effective, but without a comparable control group it cannot be definitely established. This report is concerned with chemotherapy as applied to war injuries with peritoneal penetration. During the past year of the Italian campaign we have had 243 such cases. The sulfonamides were used for approximately the first half of the year. For the latter half penicillin became available and has been used on a slightly greater number of cases. This group includes only those cases having proven peritoneal penetration, and those with subparietal injuries with perforation of the intestine, which received chemotherapy.

*Sulfonamides:* In 112 cases the sulfonamides were used exclusively. In 69 of these cases sulfonamide was applied intraperitoneally in amounts varying from 6 to 12 Gm. of sulfonamide powder at the time of operation, in addition to subsequent intravenous and oral administration. All cases routinely received 5 Gm. of sodium sulfadiazine intravenously each 24 hours for the first three or four postoperative days. As soon as oral administration was tolerated, sulfadiazine was given in doses of 1 Gm. four times daily. Its use was maintained until the patient became afebrile or from clinical indications free of danger of peritoneal infection. Rarely was it given for a period longer than seven to ten days altogether. In 60 additional cases sulfanilamide powder was applied intraperitoneally, but was followed by postoperative penicillin therapy. The sulfonamides with few exceptions were well tolerated and in no case was there a serious reaction.

*Penicillin:* In 129 cases penicillin has been used. In 60 of these sulfanilamide powder was applied locally and followed by penicillin intramuscularly; in 13 cases penicillin was used locally and followed by its intramuscular administration; and in 58 cases penicillin intramuscular only was used. The intraperitoneal dosage of the drug was 50,000 units. The intramuscular dosage was 25,000 units every three hours. Its use was kept up for a period of a week or ten days, or until the danger from peritoneal infection, as determined from clinical progress, had passed.

Although 243 cases had peritoneal penetration by missiles which undoubtedly carried in foreign material and some bacteria, and might well have had peritonitis develop from that source, only in the group with intestinal perforations did it actually occur. Hence, the cases appear in Table I so designated. The total number of deaths for the two groups is also shown. There were four deaths in the group of 86 cases without intestinal perforations and 37 deaths in the group of 157 cases with intestinal perforations.

# INTRA-ABDOMINAL CHEMOTHERAPY

Such a marked difference in the mortality is due chiefly to the fact that the latter group represents the more severely wounded, since peritoneal infection was the principal cause of death in only 12 cases. Of those 12 cases five were such that little or no benefit could be expected from chemotherapy. In the last column is shown the seven deaths from peritonitis which were thought possibly amenable to chemotherapy.

TABLE I  
TYPES OF CASES AND RESULTS OBTAINED FROM CHEMOTHERAPY

Drug	Route of Administration	No. of Cases	Deaths	Cases with Hollow Visceral Perforation	Deaths	Deaths from Peritonitis	"Preventable" Deaths from Peritonitis
Sulfonamides	Local, intravenous and oral	69	14	58	13	4	2
Sulfonamides	Intravenous and oral	43	2	16	2	2	1
Sulfanilamide } Penicillin }	Local and intramuscular	60	9	52	9	3	1
Penicillin	Local and intramuscular	13	5	9	5	2	2
Penicillin	Intramuscular	58	11	22	8	1	1
Total		243	41 (16%)	157	37 (23%)	12	7

COMMENT: Although perhaps too small a group to justify conclusions, it is our impression that the local use of either drug affords no additional protection against peritoneal infection. Our experience fails to indicate any particular advantage of one drug over the other or that their combination as employed has proven more efficacious than either alone. Indeed, it is impossible to know just to what degree either drug is effective, if at all. Of the 157 cases with hollow visceral perforation, 148 of which were of the small intestine and colon, there were only seven deaths attributed to "preventable" peritonitis—a much smaller number than would be expected without chemotherapy. That figure is even more striking when the frequency of extensive peritoneal soiling and prolonged time-intervals between wounding and operation are considered.

In addition to the infrequency of deaths from peritonitis there has been no instance of a diffuse suppurative process. We have yet to see an abdomen distended with a large quantity of free pus, as was so often found at autopsy following intestinal perforations and operations before the advent of effective chemotherapeutic agents. The peritonitis observed has been chiefly of the fibrinous plastic type, producing numerous points of mechanical obstruction and ileus. Whenever purulent exudate has been observed it has been localized. Without exception those deaths attributed to peritonitis have occurred in the most severely wounded cases, which barely escaped death from shock and only then following the use of large quantities of plasma and whole blood. At autopsy in such cases, it is difficult to ascertain whether the severe and prolonged shock, the peritonitis or the usual bronchopneumonia in the lower lobes is chiefly responsible for the fatality. We believe that it is the com-

TABLE II  
ANALYSIS OF DEATHS FROM PERITONITIS

Case No.	Diagnosis	Time Involved (Injury to Operation)	Operative Findings	Operative Procedure	Chemotherapy	Course and Autopsy Findings
1—Italian Civilian	Gunshot wound, perforating abdomen	3-4 days	Diffuse purulent peritonitis. Nine ileal perforations	Suture of perforations	Sulfonamides, locally and intravenously	Died 48 hours postoperatively
2—German P.O.W.	Shell fragment wound penetrating abdomen	3 days	Diffuse purulent peritonitis. Two ileal and one cecal perforations	Suture of perforations	Sulfonamides, locally and intravenously	Died 48 hours postoperatively
3—American Soldier	Shell fragment wound penetrating abdomen	17 hours	Multiple perforations in ileum, ascending colon and sigmoid	Two ileal resections and anastomoses; exteriorization of terminal ileum and right colon	Sulfonamides, locally and intravenously	Died 9 days postoperatively. Fibrinous peritonitis
4—American Soldier	Shell fragment wound perforating abdomen	3 hours	Transsections of ileum and transverse colon	End-to-end ileal anastomosis; ends of transverse colon exteriorized	Sulfadiazine, intravenously	Died 9 days postoperatively. Fibrinous peritonitis
5—German P.O.W.	Shell fragment wound perforating rectum	2-3 days	Diffuse purulent peritonitis; jejunal, rectal and bladder perforations	Suture of jejunal perforation, sigmoidostomy. Cystostomy	Sulfadiazine, intravenously	Died 24 hours postoperatively
6—German P.O.W.	Gunshot wound perforating bladder	22 hours	Laceration of bladder	Suture of laceration. Cystostomy	Sulfanilamide, locally. Penicillin, intramuscularly	Died 3 days postoperatively. Localized suppurative peritonitis from overlooked jejunal perforation
7—Italian Civilian	Shell fragment wound penetrating abdomen	24 hours	Early diffuse peritonitis, perforations in ileum, ascending and transverse colon	Suture of ileal and ascending colon perforations. Transverse colon exteriorized	Sulfanilamide, locally. Penicillin, intramuscularly	Died 5 days postoperatively. Diffuse fibrinopurulent peritonitis
8—American Soldier	Shell fragment wound perforating abdomen	2 hours	Transsections of ileum and splenic flexure of colon. Lacerations of spleen and left kidney, slight	Ileal anastomosis. Colon ends exteriorized	Penicillin, locally and intramuscularly	Died 8 days postoperatively. Localized suppurative peritonitis; bronchopneumonia
9—Italian Civilian	Bomb fragment wounds penetrating left chest and abdomen	9 hours	Early diffuse peritonitis; six jejunal and two descending colon perforations	Suture of jejunal perforations. Descending colon exteriorized	Penicillin, locally and intramuscularly	Died 7 days postoperatively. Localized suppurative peritonitis; bronchopneumonia
10—American Soldier	Shell fragment wound penetrating buttocks and abdomen	4 hours	Early diffuse peritonitis. Multiple jejunal and intra-peritoneal rectal perforations	Jejunal resection and anastomosis; suture of rectal perforation and proximal sigmoidostomy	Penicillin, intramuscularly	Died 10 days postoperatively. Fibrinopurulent peritonitis
11—American Soldier	Shell fragment wound perforating spine and abdomen	3 hours	Transsections of jejunum and splenic flexure of colon	Jejunal resection and anastomosis; ends of colon exteriorized	Sulfanilamide, locally and intramuscularly	Died 6 days postoperatively. Fibrinous peritonitis
12—Italian Partisan	Shell fragment wound penetrating abdomen	10 hours	Transsection of splenic flexure of colon. 3 perforations in stomach, laceration of spleen, slight. Lacerations of pancreas and left kidney	Ends of colon exteriorized; perforations of stomach sutured. Nephrectomy	Sulfanilamide, locally. Penicillin intramuscularly	Died 3 days postoperatively. Fibrinopurulent peritonitis. Bronchopneumonia

bination of those conditions which prove fatal and without the other two, recovery would frequently take place from the peritonitis alone. Certainly, without the peritonitis recovery would undoubtedly occur from shock and the pulmonary disturbance in many instances.

As indicated in Table I, there were 86 cases with peritoneal penetration, but without gastro-intestinal perforations. In no case of this group was there significant peritoneal infection.

The combined use of penicillin and the sulfonamides other than the more local application of the latter appears to have certain theoretic advantages. Recently, in a single case such was the treatment and with, thus far, a favorable outcome.

**Case Report.**—American soldier. Admitted October 16, 1944. Shell fragment wound, penetrating left lumbar region and abdomen two hours prior to admission. General condition fair. Abdomen rigid. *Operative Findings:* A large amount of blood and intestinal contents in the peritoneal cavity. Descending colon three-fourths severed. Jejunum severed in two places near ligament of Trietz and two smaller lacerations more distally. *Procedure:* Resection of three feet of jejunum with an end-to-end anastomosis. Suture of the two other jejunal lacerations. Exteriorization of injured segment of the descending colon. Through-and-through wire suture closure of abdominal incision. *Chemotherapy:* Sulfonamides administered locally, intravenously and orally; penicillin intramuscularly. *Course:* Since third postoperative day intestinal function has been satisfactory. Recovery uneventful except for operative wound infection.

As shown in Table II, Cases 1, 2 and 5 were found to have far advanced generalized suppurative peritonitis at the time of operation and could not reasonably be charged against the efficacy of chemotherapy. Case 6, with an overlooked perforation, and Case 12, with such extensive injuries and profound shock as to survive for only 72 hours, should properly be similarly considered. The seven remaining cases represent the deaths from peritonitis which were considered preventable. Four of the seven cases received penicillin and three sulfonamide therapy.

#### CONCLUSIONS

- (1) The sulfonamides and penicillin appear to be about equally effective in the treatment and prevention of peritonitis.
- (2) The local use of either drug does not appear to offer additional protection against peritonitis.
- (3) Their combined use would seem to warrant further trial.

# LUNG ABSCESS COMPLICATING PENETRATING WOUNDS OF THE CHEST

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LUNG ABSCESS following penetrating wounds of the chest have been uncommon in World War II. A British chest team<sup>1</sup> reviewed 291 cases of penetrating wounds of the chest incurred during the African Campaign and reported three cases of lung abscess following penetration of the chest, an incidence of about 1 per cent. Holman<sup>2</sup> reported 36 penetrating gunshot wounds of the chest from the Pacific Combat Area and did not mention the occurrence of lung abscess. The authors have treated 122 patients with penetrating wounds of the chest in a General Hospital operating in the Italian Theater. Among these cases were two patients that developed lung abscess, an incidence of 1.6 per cent. One developed rapidly about a large foreign body and the other was a complication of prolonged intrathoracic sepsis.

It is not clearly understood why pulmonary abscesses develop about some retained foreign bodies and not about others. It has been suggested that pieces of clothing driven into the lung by large foreign bodies may carry the infecting organisms. Skin and other extraneous foreign materials have also been blamed. It may be noted that the organisms found in the pus in Case 1 are not those usually associated with clothing and skin, but more frequently respiratory flora. The authors have removed several intrapulmonary metallic foreign bodies, along with pieces of uniform, and in these cases there was no evidence of pulmonary suppuration at the time of operation or during the convalescent period. It is probable that the heat of shell fragments is sufficient to sterilize most pathogenic organisms.

A circumscribed area of density of varying degree has been noted roentgenologically about retained metallic foreign bodies in the lung in numerous cases. Whether this is an area of pneumonitis representing infection or density caused by infiltration of blood is not clear, because practically all of these changes disappear within 10-14 days following their appearance. An elevation of temperature may or may not occur during this time.

## CASE REPORTS

**Case 1.**—This 26-year-old male was wounded in action by an enemy shell fragment on January 31, 1944. The fragment entered the right upper arm near the posterior axillary fold and traversed the right chest wall, entering the right upper lung field. Treatment in the field consisted of 4 Gm. of sulfadiazine orally, two units of

## LUNG ABSCESS

plasma (500 cc.), and a sterile dressing and sulfanilamide crystals applied to the wound. Due to the difficult line of evacuation during this particular military operation the patient was not received at this hospital until February 3, 1944, approximately 72 hours after sustaining the wound. On admission, his temperature was 102° F., pulse 122, respirations 28. He was moderately dyspneic and cyanotic, and he complained of severe pain in the right side of the chest. Hemoptysis was minimal, and a slight shift of the heart to the left was noted. The right chest was dull to percussion throughout and the breath sounds were diminished at the apex and obscured below this area. Roentgenograms

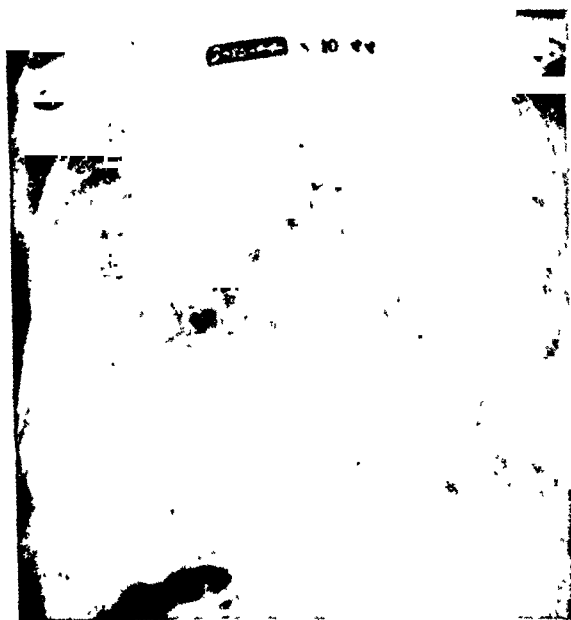


FIG. 1



FIG. 2

FIG. 1.—Extent of the abscess in Case 1 on the day of operation is shown. This was 12 days after the wound was sustained.

FIG. 2.—Lateral view in Case 1 showing the posterior position of the abscess.

showed a uniform density clouding over the entire right lung field, and a large metallic foreign body, measuring 1.5 x 3 cm., lying in the posterior part of the right chest at the level of the eighth rib, 6 cm. to the right of the spine. Treatment on admission consisted of continuous oxygen by nasal catheter and 1,000 cc. of whole blood along with sulfadiazine, 1 Gm. every four hours orally (at this time penicillin was not available for general use). Only 6 cc. of blood was obtained on thoracentesis, although the attempt to evacuate blood from the chest was made through four different interspaces. Culture of this blood proved to be sterile. Repeated roentgenograms were taken and, on February 7, seven days after injury, there was definite evidence of a lung abscess around the foreign body. Another transfusion of 1,000 cc. of whole blood was given on February 8. Further roentgenologic study revealed rapid progress in the growth of the cavity and on February 12 it measured 10 cm. in diameter. The temperature had been "spiking" daily to 103° F.

*Operation.*—February 12, 1944: Under endotracheal, nitrous oxide-oxygen-ether anesthesia, a curved incision was made posteriorly from the level of the fourth rib, laterally to the ninth rib in the axillary line. The seventh and eighth ribs were denuded of muscle and periosteum for a distance of about three inches, and the intercostal bundles in this region were excised. Examination showed that the parietal and visceral pleura were adherent, and aspiration revealed that the abscess was directly below the exposed area. Sections of both ribs were then removed and the entire roof of the abscess cavity was excised, revealing a fetid cavity containing 450 cc. of pus. The shell fragment was found free within the cavity and removed. Several small, incomplete loculations were broken down and the cavity completely emptied. It was carefully packed with strips of

tight mesh dry sheeting to include all recesses. The upper and lower poles of the wound were lightly approximated with chromic catgut.

Smears of the pus showed predominant *Spirochaetes* and fusiform bacilli, and culture revealed gram-positive spore-forming bacilli and diphtheroids predominating.

Starting on the seventh postoperative day, the packing was loosened and two to three inches removed every other day. The postoperative course was entirely satisfactory until March 3, 1944, when the patient began to have a higher elevation in temperature and complained of pain in the left thigh. On March 6, 1944, the left leg and thigh were markedly swollen and hot. The calf and anterior thigh were tender to moderate pressure. The diagnosis of acute femoral thrombophlebitis was made. Under pentothal sodium anesthesia, on the same day, the left femoral vein was exposed and found to be filled with soft, but adherent clot. The vein was divided high and doubly ligated with silk, above and below the division. There was a dramatic and almost immediate relief of pain and a rapid disappearance of swelling within one week following the vein ligation. Culture of the blood clot revealed no growth.

On March 15, 1944, penicillin was available and was given in doses of 25,000 units intramuscularly every three hours. This was discontinued on March 28, 1944, after the patient's temperature had been normal for three days. During this period of time a careful check of the hematocrit, hemoglobin, and plasma proteins was made, employing the Van Slyke copper sulfate method. Any deviation from the normal was corrected with whole blood transfusions. During his stay in this hospital the patient received a total of 4,500 cc. of whole blood.

Postoperative roentgenograms were taken at intervals, and, on May 9, 1944, the abscess cavity was no longer visualized. The patient was evacuated to the Zone of Interior on May 21, 1944, and at that time the chest was completely healed and there was no evidence of suppuration.

**Case 2.**—A 25-year-old male was wounded in action by enemy shell fragments on February 20, 1944. He sustained a large penetrating and avulsing wound of the right lower, lateral chest wall, with laceration of the lower lobe of the right lung, diaphragm and liver. He was operated upon within 12 hours at a Forward Hospital, where a partial lobectomy of the right lower lobe was done. The shell fragments were removed and the diaphragm repaired. The liver was packed and drained through a subcostal stab wound. He developed an empyema, which was drained through the original wound.

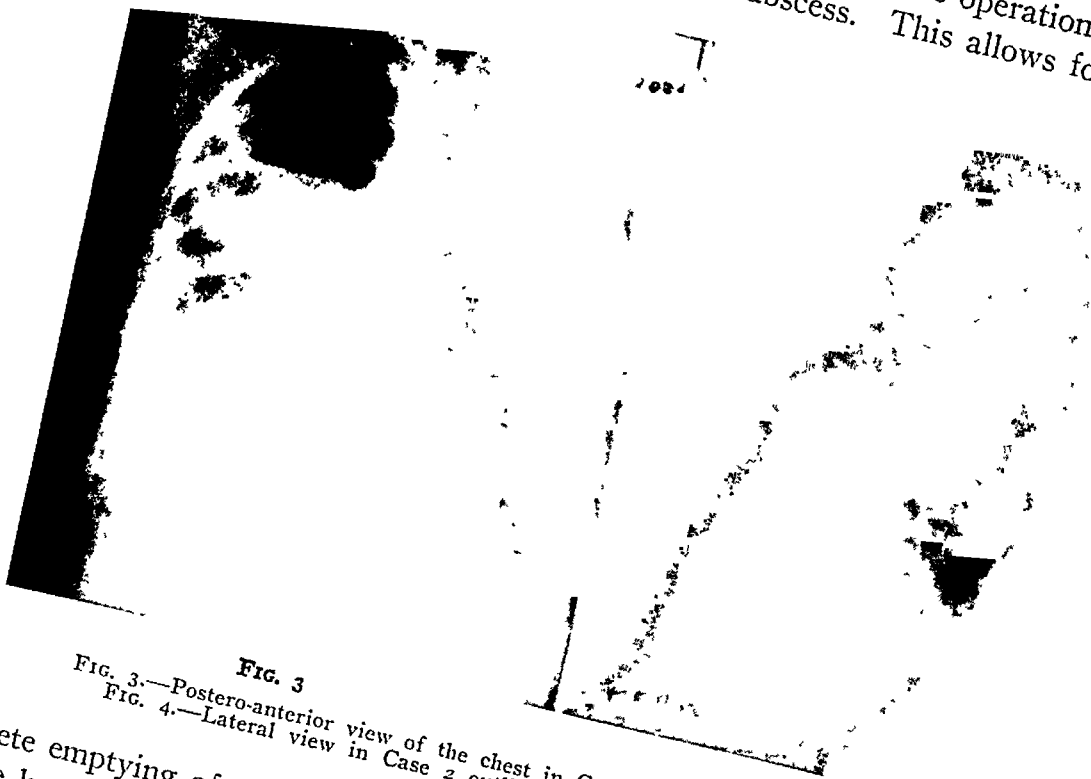
He was admitted to this hospital, March 7, 1944, in poor condition. His temperature was 102.8° F., pulse 128, respirations 30. There was a huge, open suppurating wound of the right lower chest wall, measuring 20 x 9 cm. Roentgenograms revealed a total clouding of the right lung field. Thoracentesis was done, and a thin, nonfetid purulent exudate was obtained. Oral sulfadiazine and blood transfusion therapy was started on admission. On March 9, 1944, a closed intercostal thoracotomy was done, with water-tight drainage. A large amount of pus was evacuated and culture showed a predominant growth of *Staphylococcus aureus*. In spite of this apparently adequate drainage the patient continued to run a febrile course and subsequent roentgenologic studies showed the presence of a large lung abscess in the right midlung field. Penicillin therapy was started on March 16, 1944, and 25,000 units were given every three hours intramuscularly, along with necessary blood transfusions. The patient showed a marked tendency toward anemia, and the hematocrit, hemoglobin and plasma proteins, employing the Van Slyke copper sulfate method, were frequently much below normal. On March 22, 1944, the patient was operated upon, employing essentially the same technic as in Case 1. Culture from the pus in this abscess showed predominant *non-hemolytic Streptococci* and diphtheroids.

The healing of the abscess in this patient was exceptionally rapid, and roentgenograms demonstrated complete obliteration of the cavity on April 24, 1944. The large chest wall wound was healing well by granulation and the operative wound over the

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abscess was almost completely healed when the patient was transferred to a Canadian General Hospital on May 18, 1944.

**COMMENTS:** The one-stage operation for drainage of lung abscess was favored in these patients because it was possible to make accurate roentgenologic localization of the abscesses, showing their proximity to the periphery. The fact that they were large solitary lesions also favored the one-stage procedure. The essential feature in the technic of the operation is not simple drainage, but complete unroofing of the abscess. This allows for more com-



**FIG. 3**

FIG. 3.—Postero-anterior view of the chest in Case 2 showing the huge abscess cavity.

**FIG. 4**

FIG. 4.—Lateral view in Case 2 outlining the posterior position of the abscess.

plete emptying of the cavity and, subsequently, a more rapid reëxpansion of the lung and obliteration of the pyogenic membrane. Dry, tight-mesh packing, placed into the cavity to include its entire surface, is favored over vaselined gauze. Vaseline produces unwanted maceration, and there is always the fear of aspiration of some of the vaseline through a small bronchial fistula, with the possibility of lipoid pneumonia complicating the picture.

The completeness with which these cases healed may be attributed to adequate drainage plus the use of penicillin and blood transfusions. It is believed by the authors that, although drainage in this type of lung abscess is without question the most important step, penicillin and the intelligent use of whole blood contribute greatly to the recovery of these patients. It seems logical that whole blood presents the best means available for replacing body elements lost by suppuration.

Neuhof and Hurwitt<sup>3</sup> speak of the problem of wound closure following the drainage of lung abscess and mention the persistence of anaerobic infection in the wounds as the reason for the difficulty in achieving early and



complete healing. The use of whole blood transfusions combined with penicillin therapy has been shown to be of great value in controlling infections in war wounds of all types. It is logical that the application of these principles to the treatment of lung abscess may be a very valuable adjunct to surgical drainage. It must be stressed that 500 cc. of blood does not always constitute an adequate transfusion, but that transfusions of 1,000 cc. of whole blood are more likely to give the desired result.

In Case 2 frequent checking of the hematocrit, hemoglobin and plasma proteins, by Van Slyke's copper sulfate method, revealed a marked tendency toward anemia, and a slight decrease in the plasma protein level so frequently seen in patients with chronic suppurating lesions. A total of 9,500 cc. of whole blood was administered to the patient in order to maintain a relatively normal blood picture.

#### SUMMARY

(1) The occurrence of lung abscess following penetrating wounds of the chest has been uncommon in our experience.

(2) Two cases of lung abscess following penetrating wounds of the chest are presented and discussed.

(3) The usefulness of whole blood transfusions and penicillin is stressed as a valuable adjunct to adequate surgical drainage of lung abscesses.

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# THE OPERATIVE TREATMENT OF DECUBITUS ULCER

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DECUBITUS ULCER is an unfortunate, sometimes unavoidable complication of this war. Let there be but a short period, perhaps only a few hours, in the chain of evacuation of one of these battle casualties, during which time the patient is allowed to lie on his back or side without frequent turning and change of linen, and the sacral or trochanteric ulcer is already present.<sup>1</sup> Needless to say, vigorous steps to eliminate this complication in paraplegic casualties have already been taken.

Paraplegic casualties in many ways are a challenging problem in the General Hospital in the United States. In order to prepare them for the ambitious program of rehabilitation designated for them by the Medical Department, sepsis must be controlled, especially ascending urinary infection, malnutrition must be corrected by restoring positive nitrogen balance, decubitus ulcers must be healed, and an attempt must be made to secure an automatic bladder if possible.

Confronted with such a problem, the old approach to the treatment of decubitus ulcer is entirely inadequate. No matter what local medicaments are used, it still requires six to 12 months for the complete epithelization of a large sacral ulcer. Moreover, the end-result leaves much to be desired since a thin unstable epithelium overlies the bony structure of the sacrum and coccyx with but a thin layer of fibrous tissue intervening. If the patient is destined to remain a paraplegic, this epithelium is readily subject to the vicissitudes of unavoidable abuses, especially if the area remains anesthetic, as a result of which it may ulcerate repeatedly. If the patient recovers, the result may be still more unsatisfactory.

Cautiously at first, but with increasing vigor, the Medical Department attacked the problem. About a year ago, the military surgeons began to cover cleanly granulating ulcers with free grafts. A few used pinch grafts, others employed Thiersch grafts. Some of the results were gratifying, the ulcers being completely epithelized in a relatively short period. In retrospect, there is little to be said for the use of pinch grafts. The ulcer may be completely epithelized somewhat sooner, but it still requires months to secure complete healing, and the end-result is hardly better than that of the nonoperative treatment. The use of split-thickness skin grafts to completely cover the ulcer has much more to be said in its favor, for the healing time is thereby greatly shortened. The end-result is, however, only slightly

better than either the nonoperative, or the pinch-graft method of treatment, in its ability to withstand trauma.

Several months ago we began to observe several primary closures of small decubitus ulcers, by excision, undercutting and midline approximation in patients *en route* to other General Hospitals. Healing had occurred *per primam*, and the skin, with its normal subcutaneous padding, appeared quite normal. It seemed to us that closure by the use of sliding full-thickness grafts would be the ideal solution if it could be universally applied. Obviously, a simple linear closure could not be applied in the surgical treatment of the larger ulcers.<sup>2</sup> Could not these be primarily closed by some modification of this method? The skin from the iliac crest above, to the gluteal fold below and to the trochanters laterally, is fairly loose and free. The loss of subcutaneous fat and the atrophy of the glutei renders it even more so in our paraplegics. By the simple expedient of raising a full-thickness flap on each side of the ulcer, employing curvilinear incisions laterally along the iliac crest above, and the buttock below, we found it possible to rotate these flaps centripetally to cover even large defects. The extent of the surgery required to raise flaps sufficiently adequate to close the larger defects, was at first rather startling, and some of our earlier and larger ulcers were closed in two stages. With increasing experience in the placing of incisions to take full advantage of all the available adjacent loose skin, the number of our two-stage closures has rapidly diminished.

When is a patient ready for such an operation? Obviously, a debilitated or exhausted patient should not be subjected to such a major procedure, even if anesthesia is unnecessary. His healing power is poor, and he has little resistance against infection. First, the patient should be fully recovered from spinal shock. Second, he should exhibit a distinctly positive nitrogen balance for several weeks, as indicated by an improvement in strength and general well-being, a definite gain in weight, and local signs of healing. Third, the ulcer must be free from clinical signs of acute inflammation, its base covered with healthy granulation tissue free from sloughing fascia, and its margins fixed and circumscribed with invading epithelium. Cultures have been taken routinely, but only the presence of a *Streptococcus hemolyticus* or a *Staphylococcus aureus* (coagulase-positive) have deterred surgical intervention. The less pathogenic *Clostridia* and *B. pyocyaneus* have sometimes been inhabitants of these ulcers, but have been disregarded.

Preoperatively, the patient is given a high caloric, high protein diet supplemented with vitamins. Plasma, blood, and amino-acid infusions are used freely if indicated. As long as infection or sloughing tissue is present, daily gauze dressings moistened with penicillin solution, 250 units per cc. are used locally. Thereafter, simple fine-mesh gauze dressings impregnated with a little xeroform ointment are applied daily after dusting the granulations with plasma-penicillin powder.<sup>3</sup>

At operation, most of the patients require no anesthesia. The ulcer (Fig. 1) is completely excised, including the peripheral scar tissue, and if

# TREATMENT OF DECUBITUS ULCER

contracted and bloodless, its granulation tissue base (Fig. 2). An attempt to approximate the lateral margins of the defect in a midline linear closure, even after extensive lateral undercutting, would be unsuccessful in the larger ulcers. By making curvilinear incisions on each side from the superior

FIG. 1

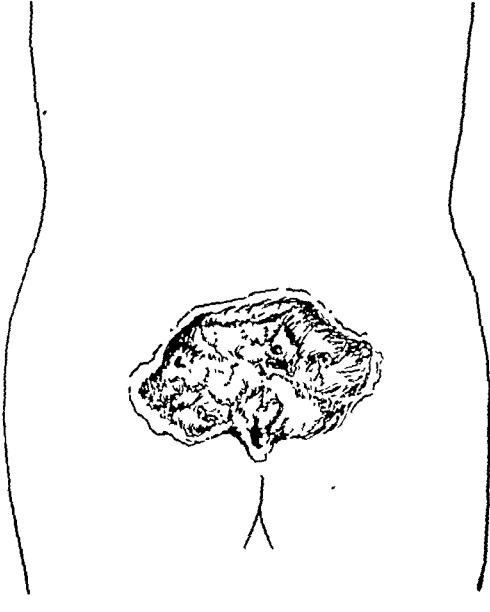


FIG. 2

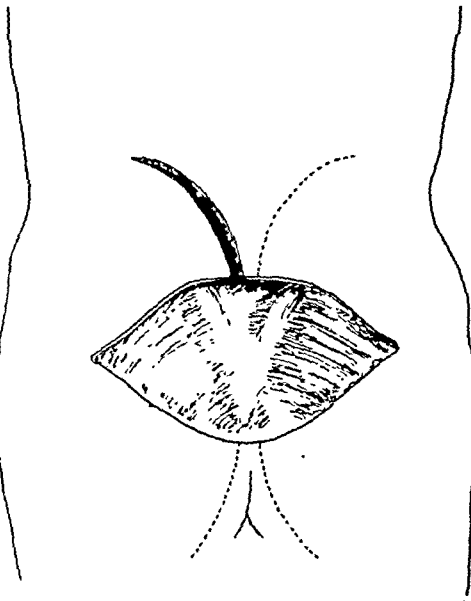
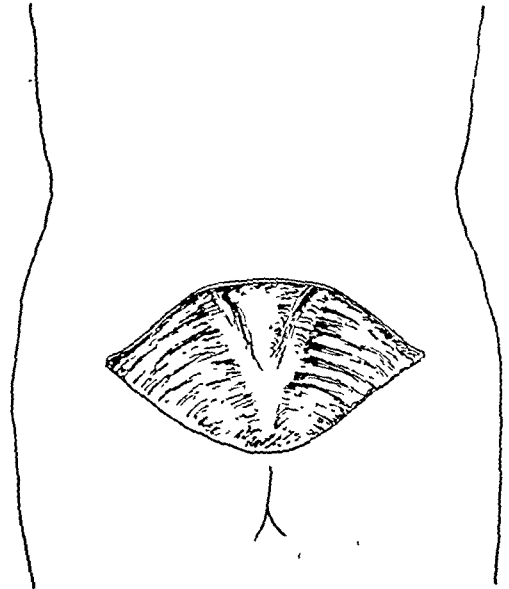


FIG. 3

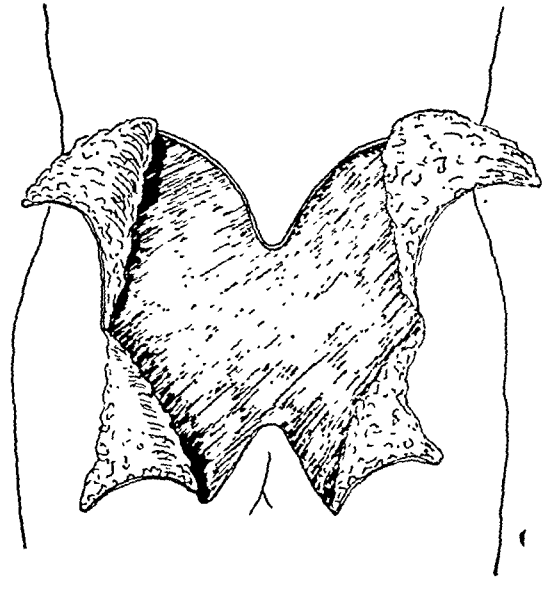


FIG. 4

FIG. 1.—Preoperative appearance of a sacral ulcer.  
FIG. 2.—The ulcer after excision of all peripheral scar tissue and its granulation tissue base.  
FIG. 3.—Drawing showing position and extent of curvilinear incisions.  
FIG. 4.—Drawing showing the four sector flaps completely dissected.

midline of the defect outward above the iliac crests and from the inferior midline outward and downward into the buttocks, two sector flaps are raised on each side, varying in size according to the shape of the defect (Figs. 3 and 4). The denuded area may now be closed by rotating the sector flaps of

each side toward each other horizontally and, finally, those of one side to those of the other (Figs. 5 and 6).

There are many details the observance of which seems to be essential to a successful outcome. Some of these embrace fundamental principles of good surgery—the excision of all scar tissue; the avoidance of trauma; meticulous hemostasis; the use of very fine nonabsorbable sutures; and

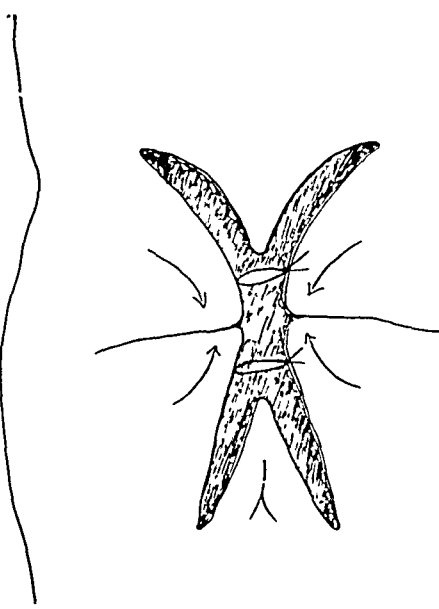


FIG. 5

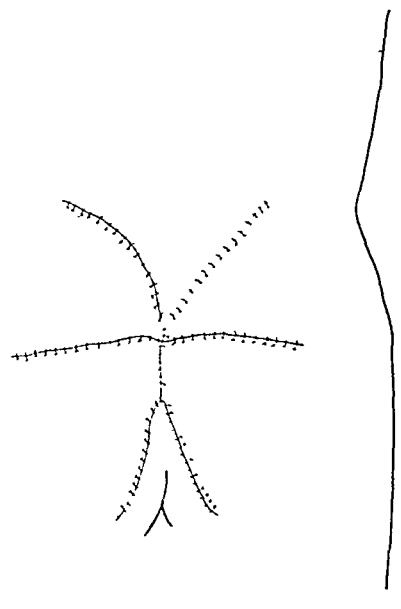


FIG. 6

FIG. 5.—Drawing showing two sector flaps of each side already approximated, and ready for approximation to those of the other side.

FIG. 6.—Drawing showing final result following complete closure.

avoidance of tension. Others are peculiar to the region. The flaps are usually best developed in the plane overlying the deep fascial investment of the glutei where the least number of vessels are encountered. The sub-section should be carried some distance lateral to the sacral origin of glutei, else a ridge of muscle will be raised on each side, lifting the medial portion of each approximated flap from the surface of the sacrum, and leaving a dead space for the accumulation of serum. For this reason, also, the lower sector raised from the buttock on each side should carry a rather thick layer of fat to reach the receding coccyx, after the flap is rotated upward and inward. Too much fat should not be left overlying the sacrum, since fatty tissue does not resist trauma well and its blood supply is poor. In making the superior curvilinear incisions, one should avoid the bony prominences of the posterior superior spines. Before closure, the entire wound should be thoroughly irrigated with physiologic saline solution, and, after final and complete hemostasis, a liberal amount of plasma-penicillin powder should be evenly distributed over the wound surfaces.

Postoperatively, we have used a pressure dressing, incorporating mechan-

## TREATMENT OF DECUBITUS ULCER

ic's waste under an Ace bandage circularly applied about the lower trunk. If indicated by the presence in the preoperative culture of penicillin-sensitive organisms, penicillin is administered for four to five days after operation. Otherwise, sulfadiazine is administered.

FIG. 7

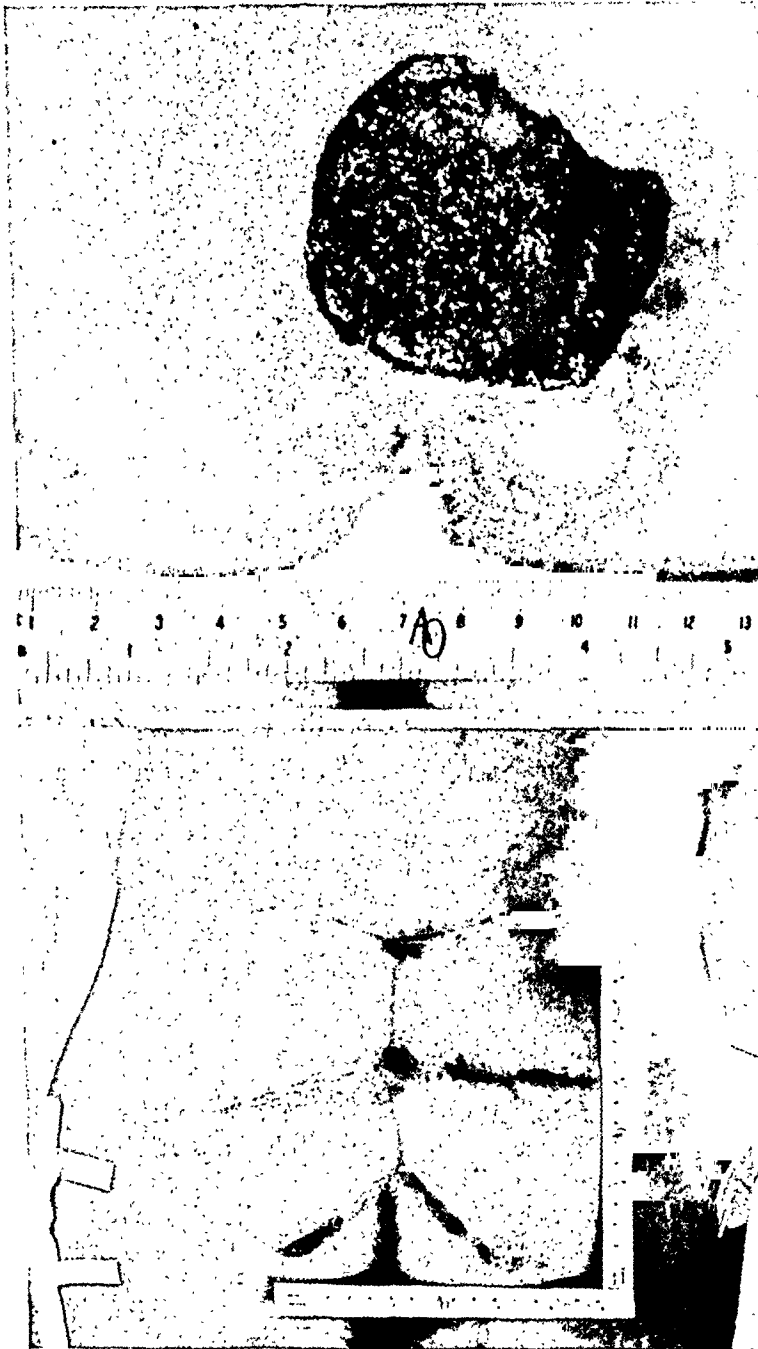


FIG. 8

FIG. 7.—Case 1: Preoperative appearance of sacral ulcer.

FIG. 8.—Case 1: Photograph of wound two months after operation.  
Note battle wound of left lumbar region.

Postoperatively, the patient is placed in a Stryker frame four hours in the prone, and one-half hour in the supine position. Unless otherwise indicated, the dressing is not disturbed for five days, when alternate sutures are

removed. The remainder are removed in the next five days. The preoperative caloric and vitamin regimen is continued after operation. Within a month after operation, the patient is receiving the same care as the paraplegic patient without decubitus ulcer, *i.e.*, he alternates between the supine and prone position every two hours, sleeps in the usual army bed, with inner-spring mattress, and is allowed out of bed in a wheel chair.

## REPORT OF CASES

## Case 1

1. Date of injury: January 28, 1945.
2. Level of nerve injury: Cauda equina roots of L3 to S5, bilateral.
3. Probable date and circumstances of onset of ulcers: Patient sustained abdominal injuries requiring emergency celiotomy. Following operation he remained flat on his back for eight days. Bed linen was changed once daily. On February 7, 1945, ten days after injury, a large sacral decubitus ulcer was noted.
4. Size of ulcer before operation: 9 x 9.5 cm. (Fig. 7).
5. Laboratory data:

	Urinalysis	Plasma Protein
R.B.C., 3.6 million per cu. mm.	1+ albumen	7.9 Gm. per cent
Hb., 11.2 Gm. per cent.	Rare red blood cell	
Bacteriology: Aerobic:	<i>A. aerogenes</i> <i>B. proteus</i> <i>Staphylococcus aureus hemolyticus</i> <i>Staphylococcus albus</i>	
	Anaerobic: No growth	

6. Operation and Date: April 11, 1945: Anesthesia, endotracheal, nitrous oxide-ether. Excision and primary closure, all silk technic.

7. Postoperative Course: There was uneventful healing *per primam* except for a 1-cm. separation at the confluence of the four flaps. The wound was completely healed in three weeks. The patient was not allowed out of bed because of an osteomyelitis of the left sacro-iliac joint of traumatic etiology. There has been no secondary ulceration (Fig. 8).

## Case 2

1. Date of injury: December 6, 1944.
2. Level of nerve injury: Seventh dorsal segment, complete.
3. Probable date and circumstances of onset of ulcer: Patient sustained a fracture dislocation of 7-8 D vertebrae, and blast injury to the lung. He was placed in an hyperextension encasement, and had pulmonary complications requiring the use of continuous oxygen therapy for several weeks. During this period, his condition was precarious. He was not turned to the prone position. On January 12, 1945, a sacral decubitus was well-developed.
4. Measurement of ulcer before operation: 6 x 5 cm. (Fig. 9).
5. Laboratory data:

	Urinalysis	Plasma Protein
R.B.C., 4.55 million per cu. mm.	2+ albumen	5.8 Gm. per cent
Hb., 12.7 Gm. per cent	5-10 red blood cells	
Bacteriology: Aerobic:	<i>Ps. aeruginosa</i>	
	Anaerobic: No growth	

## TREATMENT OF DECUBITUS ULCER

6. Operation: 1. March 23, 1945: Partial closure. No anesthesia. A central diamond-shaped defect approximately 4 cm. wide and 4 cm. long remained. 2. April 10, 1945: Secondary closure. No anesthesia.

FIG. 9

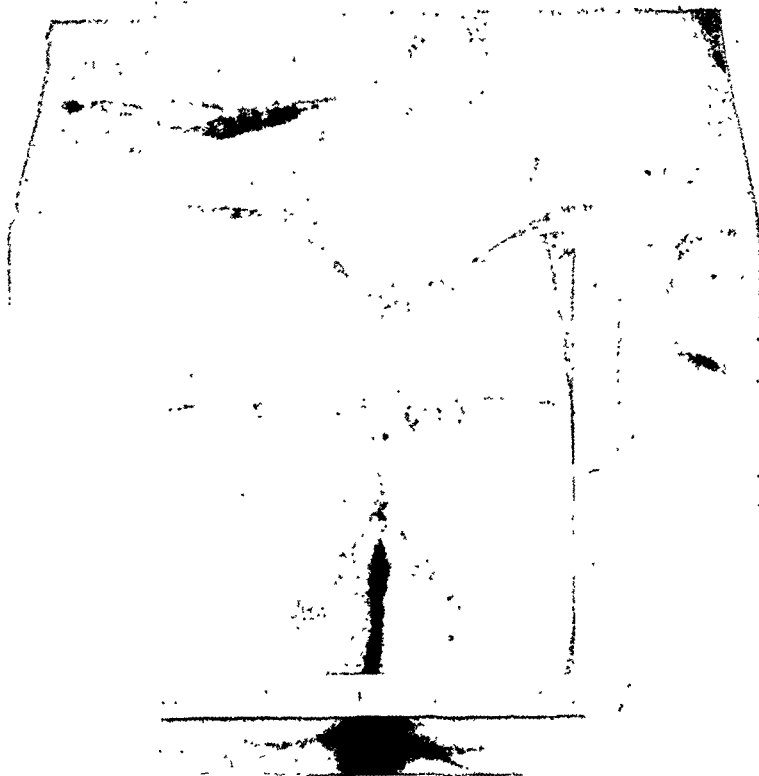
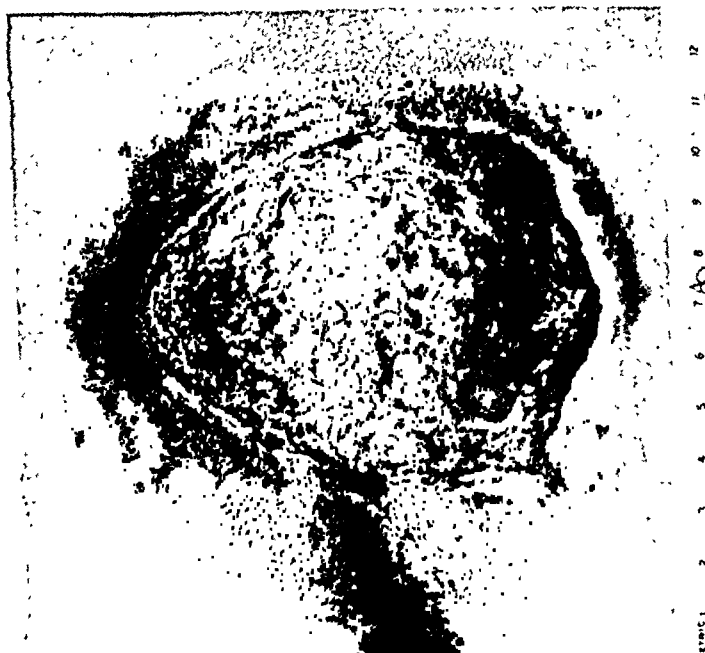


FIG. 10

FIG. 9.—Case 2: Preoperative appearance of sacral ulcer.

FIG. 10.—Case 2: Photograph of wound six weeks after closure.

7. Postoperative Course: The defect remaining after the first operation granulated cleanly. There was some separation of the suture lines at the margins of the defect. After the second operation the wound healed *per primam*. He was out of bed in about 35 days. There has been no secondary ulceration (Fig. 10).



## Case 3

1. Date of injury: January 24, 1945.
2. Level of nerve injury: Fifth dorsal segment.
3. Probable date and circumstances of onset of ulcer: Following injury patient was passed rapidly through a chain of evacuations lasting two weeks, during which he remained on his back almost continuously, and usually on blanket litters. Ulcer first noted on February 10, 1945.



FIG. 11.—Case 3: Preoperative appearance of sacral ulcer.

4. Measurement of ulcer before operation: 15.5 cm. x 11 cm. (Fig. 11).
5. Laboratory data:

	Urinalysis	Plasma Protein
R.B.C., 3.89 million per cu. mm.	1+ albumen	7.5 Gm. per cent
Hb., 12.3 Gm. per cent		

Bacteriology:      Aerobic:      *A. aeruginosa* *Staphylococcus albus*, *Streptococcus nonhemolyticus*, *Ps. aeruginosa*

Anaerobic: None

6. Operation: 1. April 6, 1945: Excision. Partial closure. T-shape, leaving 2.5-4 cm. midline defect along entire upright limb of T. Anesthesia: None. 2. April 19, 1945: Secondary closure, complete, no anesthesia.

7. Postoperative Course: The defect remaining after first operation granulated without infection. Healing occurred *per primam* after the second operation except for the appearance of a small seroma. The serum was aspirated and no infection supervened. Patient was out of bed in one month. There has been no recurrence of ulcer (Fig. 12).

## Case 4

1. Date of injury: November 9, 1944.
2. Level of nerve injury: L2, complete.
3. Probable date and circumstances of onset of ulcer: Unknown. Patient had skin grafts on January 18 and 25, and February 14, 1945.
4. Measurement of ulcer before operation: 12.5 x 10 cm. (Figs. 13 and 14).
5. Laboratory data:

# TREATMENT OF DECUBITUS ULCER

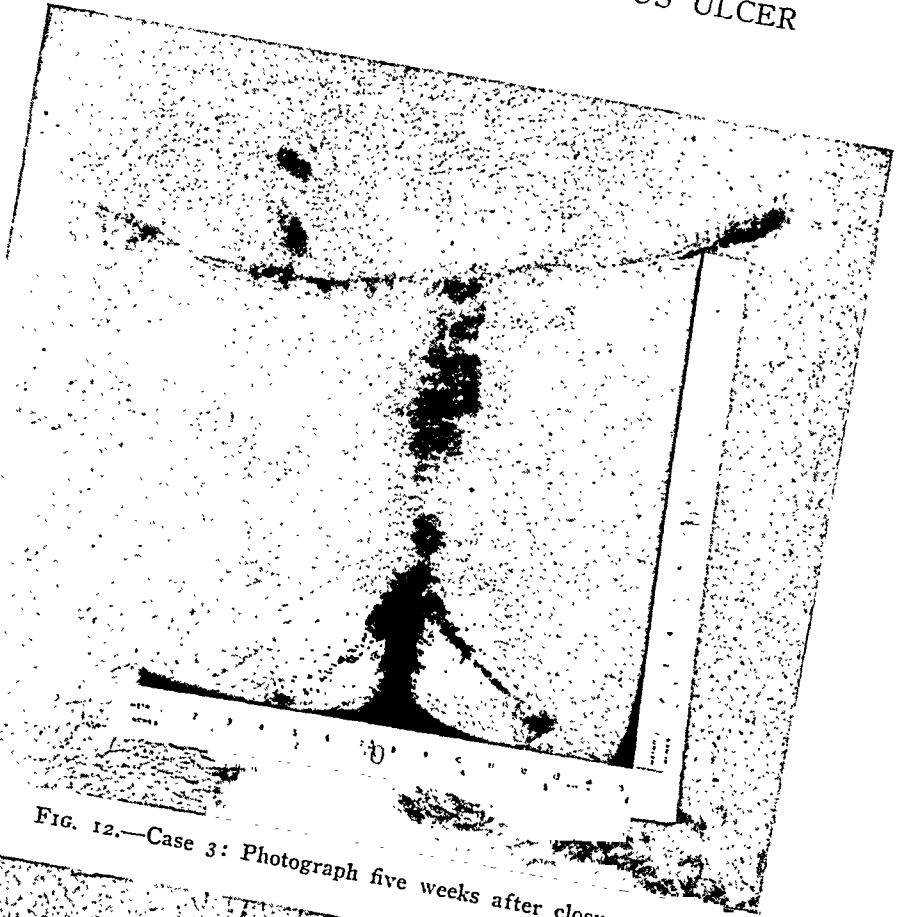


FIG. 12.—Case 3: Photograph five weeks after closure.

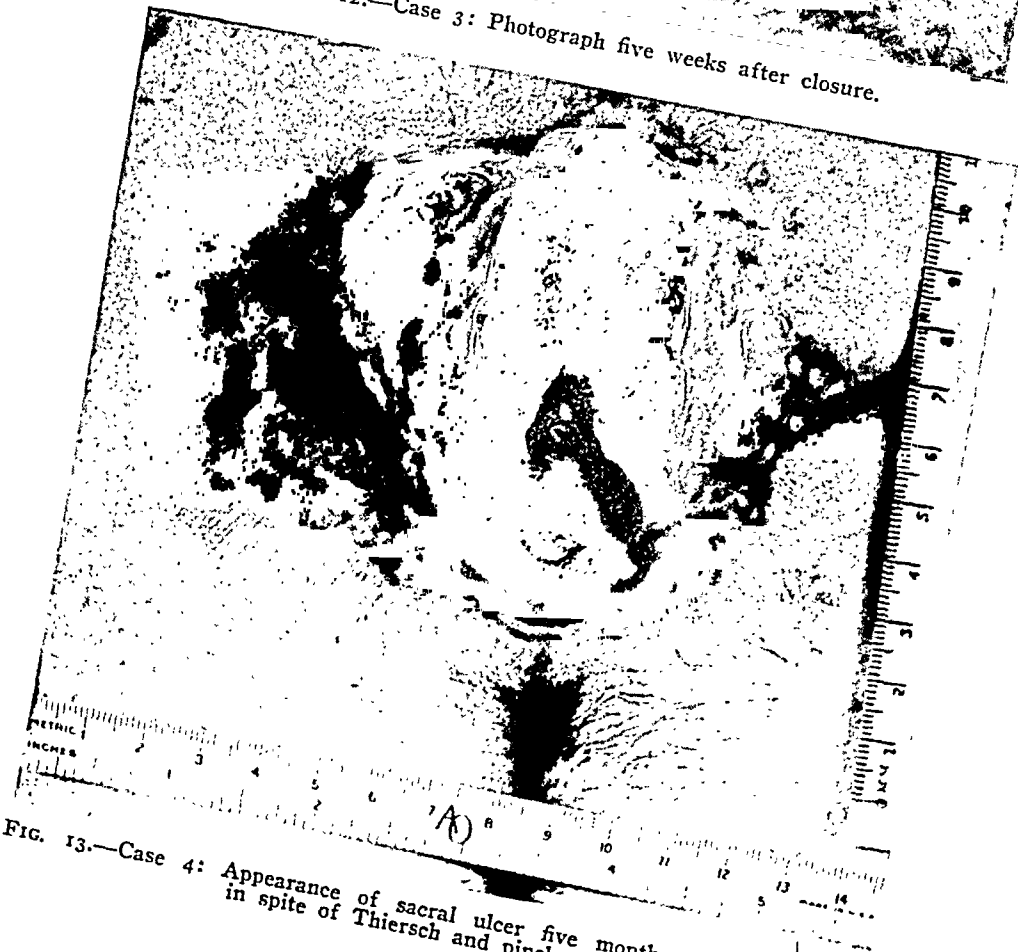


FIG. 13.—Case 4: Appearance of sacral ulcer five months after occurrence, in spite of Thiersch and pinch grafts.

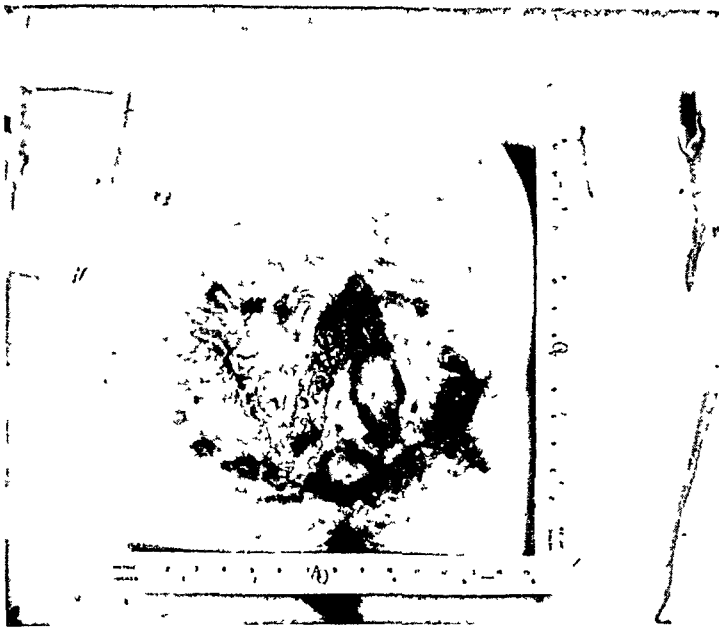


FIG. 14.—Case 4: Photograph showing secondary ulcerations of grafted areas, despite good nursing care.

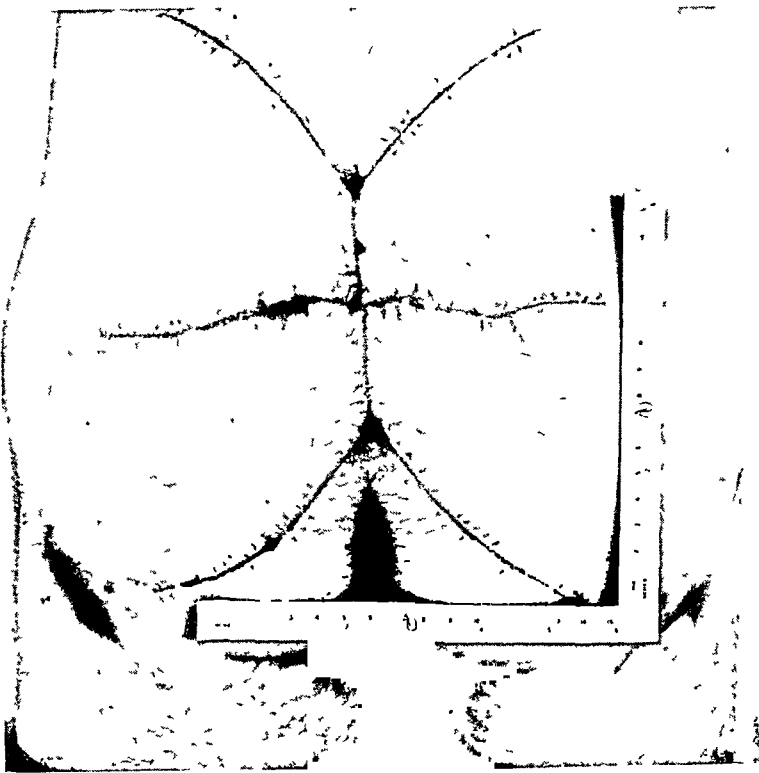


FIG. 15.—Case 4: Photograph two weeks after closure.

# TREATMENT OF DECUBITUS ULCER

R.B.C., 4.34 million per cu. mm.  
Hb., 12.7 Gm. per cent

## Urinalysis

1+ albumen  
Rare red blood cells

Plasma Protein  
6.8 Gm. per cent

## Bacteriology:

Aerobic:

*Ps. aeruginosa*  
*B. proteus*

Anaerobic:

*Streptococcus nonhemolyticus*  
Negative

6. Operation: May 17, 1945, primary closure under endotracheal inhalation anesthesia.
7. Postoperative Course: Uneventful primary healing occurred (Fig. 15). Three weeks after operation, following six hours continuous sitting on a wheel chair, a few small ulcerations developed under the inferior right flap. These are now healing and will not seriously impair the end-result.

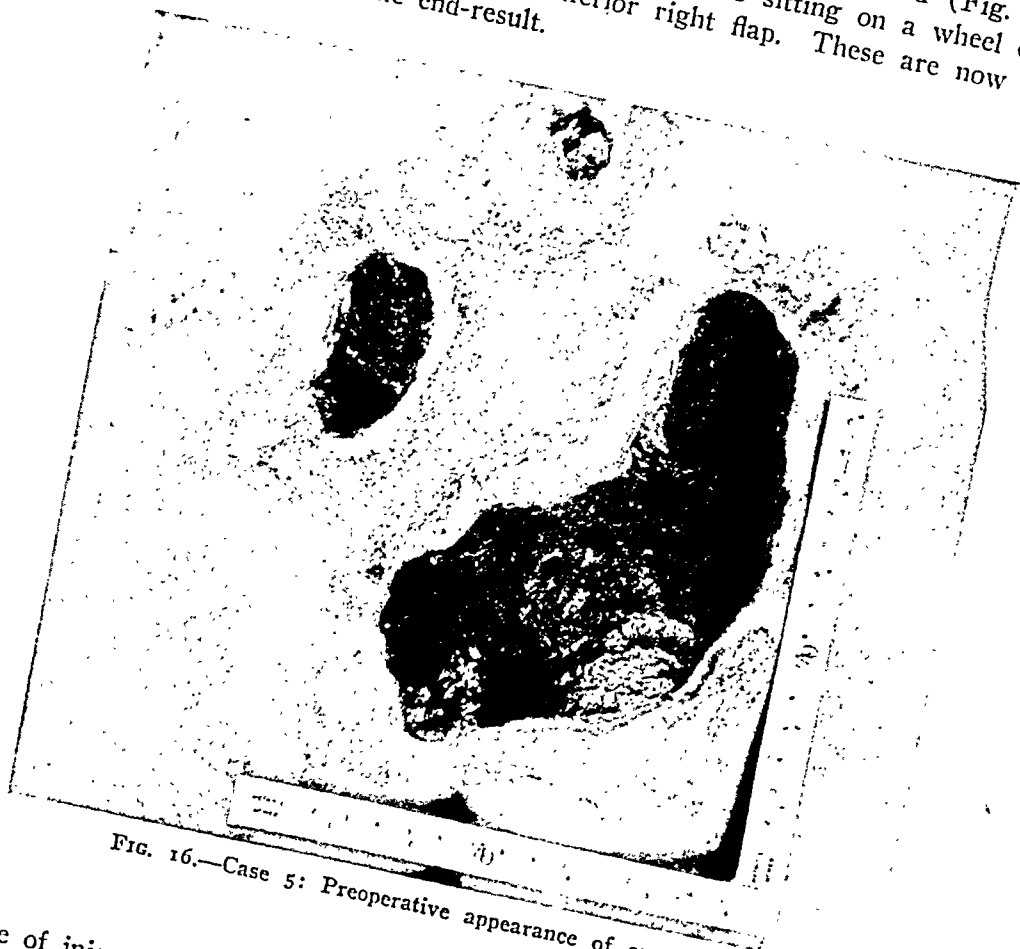


FIG. 16.—Case 5: Preoperative appearance of sacral ulcer.

## Case 5

1. Date of injury: December 30, 1944.
2. Level of nerve lesion: D12, complete.
3. Probable date and circumstances of onset of ulcer: Patient states that for the first eight to 12 days after injury he was continuously on his back on a blanket litter, without turning and without linen. The ulcer was first noted at the end of this period when he was transferred to an hospital ship.
4. Measurement of ulcer before operation: 14.5 x 14.5 cm. (Fig. 16).
5. Laboratory data:

R.B.C., 3.65 million per cu. mm.  
Hb., 11.2 Gm. per cent

## Urinalysis

1+ albumen  
8-10 white blood cells  
2-3 red blood cells

Plasma Protein  
6.3 Gm. per cent

Bacteriology:      Aerobic:    *B. proteus*  
    *E. coli*  
    *A. aerogenes*  
    *Streptococcus nonhemolyticus*  
                                  Anaerobic: *Clostridium butyricum*

6. Operation: April 24, 1945, primary closure, without anesthesia.

7. Postoperative Course: Primary healing uneventful (Fig. 17). Patient was out of bed about one month after closure.



FIG 17—Case 5. Appearance one month after closure. Note small pressure sores over spinous processes, which were not operated upon

#### Case 6

1. Date of injury: January 20, 1945.
2. Level of nerve injury: D5, complete.
3. Date and circumstances of onset of ulcer: Patient was placed in a body encasement following injury, and for the next two weeks was passed through a rapid chain of evacuations. During this period he was turned and his linen was changed infrequently. The ulcer was first noted on January 27, 1945.
4. The size of ulcer before operation: 12 x 17 cm (Fig 18).
5. Laboratory data:

	Urinalysis	Plasma Protein
R.B.C., 3.68 million per cu. mm.	1+ albumen	7.5 Gm. per cent
Hb, 11.2 Gm. per cent	Numerous white blood cells	
	2-3 red blood cells	

# TREATMENT OF DECUBITUS ULCER

Bacteriology:      Aerobic:    *Ps. aeruginosa*  
    *Aerobacter aerogenes*  
    *Streptococcus nonhemolyticus*

Anaerobic: Negative

6. Operation: May 7, 1945, primary closure, without anesthesia.

7. Postoperative Course: There was an early slight flare about central suture lines which disappeared without suppuration in seven to eight days (Fig. 19). Patient is now out of bed.

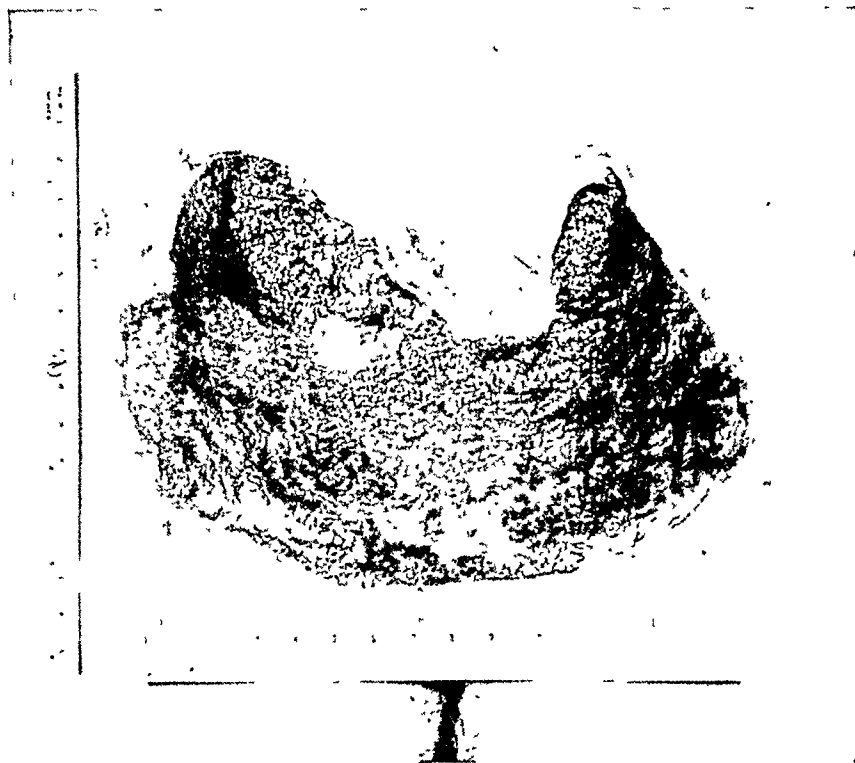


FIG. 18.—Case 6: Appearance of sacral ulcer before operation.

## Case 7

1. Date of injury: February 1, 1945.
2. Level of nerve injury: D10, severe.
3. Date and circumstances of onset of ulcer: After injury, patient was not turned because of a fracture of the right shoulder. During the first week he remained on his back on blankets. A sacral decubitus was first noted on February 10, 1945.
4. Size of ulcer before operation: 9.5 x 9 cm. (Fig. 20).
5. Laboratory data:

	<i>Urinalysis</i>	<i>Plasma Protein</i>
R.B.C.	1+ albumen	7.6 Gm. per cent
Hb., 14.6 Gm. per cent	5-8 white blood cells	
Bacteriology:      Aerobic:	<i>E. coli</i>	
	<i>B. proteus</i>	
	<i>Ps. aeruginosa</i>	
	<i>Streptococcus nonhemolyticus</i>	
	<i>Staphylococcus aureus nonhemolyticus</i>	
	<i>Cl. butyricum</i>	

Anaerobic: None

*nonhemolyticus, Cl. butyricum.* Anaerobic: None.

5. Operation: May 3, 1945, primary closure under endotracheal inhalation anesthesia.

6. Postoperative Course: Primary healing occurred (Fig. 21). Patient was allowed out of bed in one month.

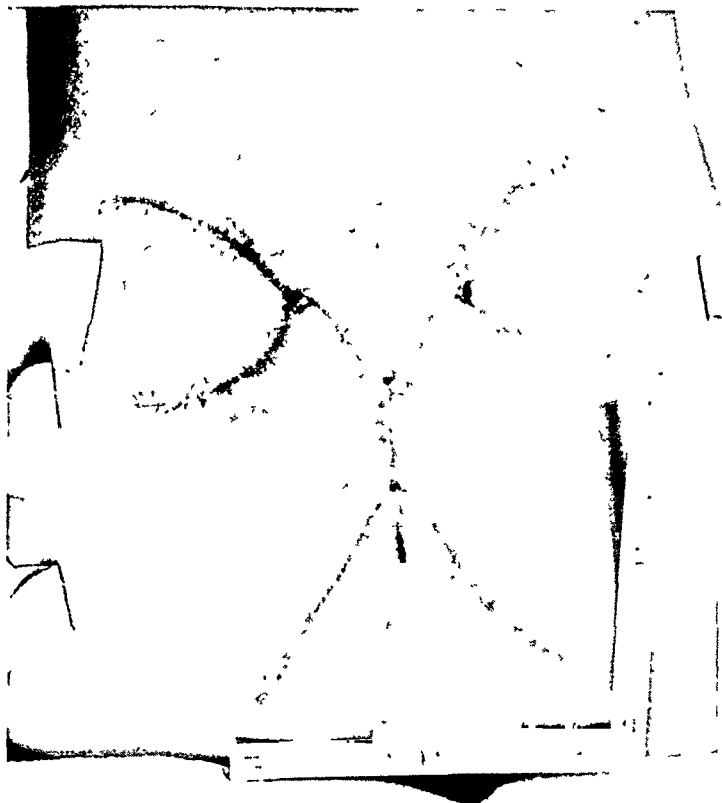


FIG. 19.—Case 6: Appearance three weeks after operation.

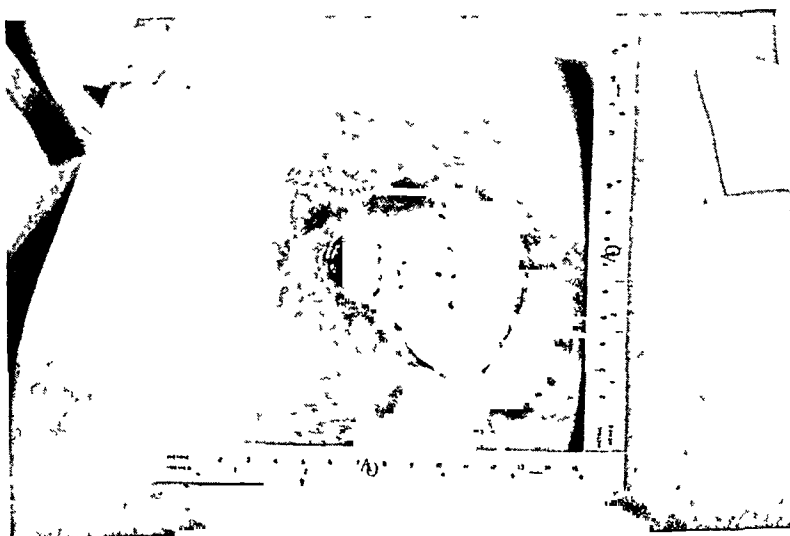


FIG. 20.—Case 7: Appearance of sacral ulcer before operation.

## TREATMENT OF DECUBITUS ULCER

### Case 8

1. Date of injury: February 9, 1945.
2. Level of nerve injury: 10D, complete.
3. Date and circumstances of onset of ulcer: During the first few days, patient states he was passed through a rapid chain of evacuations during which he was turned infrequently and there was little change of linen. A sacral decubitus was first noted on February 13, 1945.
4. Size of ulcer before operation: 13 x 11 cm. (Fig. 22).
5. Laboratory data:



FIG. 21.—Case 7: Appearance one month after closure. Deeply pigmented areas were not excised.



FIG. 22.—Case 8: Appearance of sacral ulcer before operation



*Urinalysis*

R.B.C., 4.57 million per cu. mm. 1+ albumen  
Hb., 13.2 Gm. per cent

*Plasma Protein*

6.2 Gm. per cent

Bacteriology: Aerobic: *E. coli*  
*B. proteus*  
*Streptococcus nonhemolyticus*  
*Pseudomonas*  
*Ps. aeruginosa*

Anaerobic: *Clostridium septicum*

6. Operation: May 9, 1945, primary closure, without anesthesia.

7. Postoperative Course: Primary healing occurred except for the accumulation of a little sterile serum beneath one of the flaps (Fig. 23). Patient was out of bed in one month.

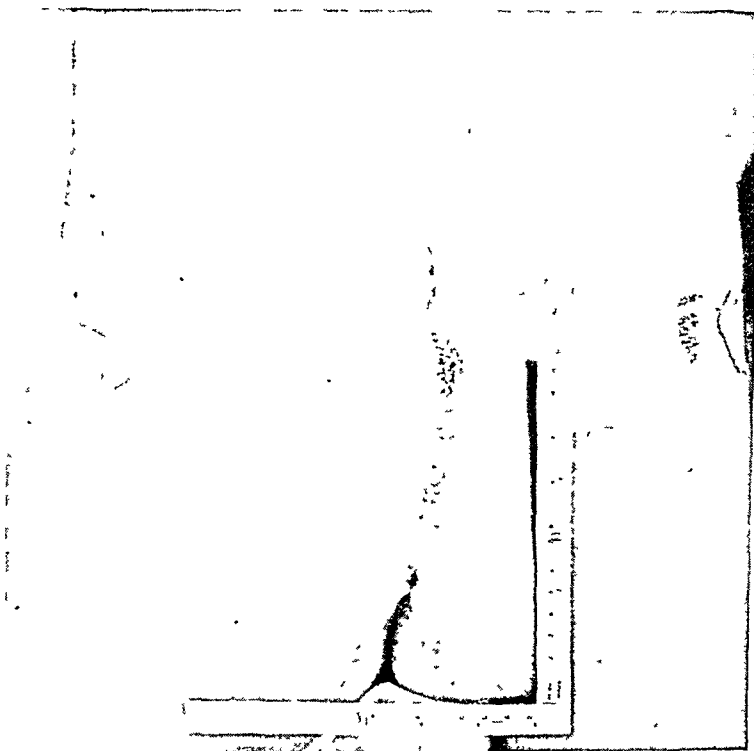


FIG. 23.—Case 8: Appearance three weeks after operation. Note battle wound of left lumbar region.

## SUMMARY AND CONCLUSIONS

A method for primary closure of decubitus ulcers in young paraplegic casualties has been presented. Given the same back care postoperatively as the paraplegic without bed sore, the results seem to be quite as durable as the unbroken normal skin. The method seems to be applicable to the largest sacral ulcers. With rare exception, the results may be obtained by single-stage procedure. A period of careful preoperative preparation and evaluation is just as important as the technic of the operation itself.

Case 4 illustrates how unsatisfactory pinch and small thin Thiersch grafts may be. After repeated secondary ulcerations, the entire ulcer and scar were excised and the area covered with sliding full-thickness grafts.

All the patients herein reported are now participating in a rehabilitation program intended to strengthen the upper part of the body for better mobilization, and are being educated in a gainful occupation.

Whether the method described is applicable to the sacral decubitus ulcer in older bed-ridden patients is problematic. The operation is a major plastic procedure and should not be attempted in a debilitated patient.

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# THE RÔLE OF CHEMOTHERAPY IN WOUNDS AND SURGICAL INFECTIONS

I—CLINICAL AND BACTERIOLOGIC STUDIES\*

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THE AUTHORS have, for the past two years, been jointly engaged in a study of the effect of bacteriostatics in fresh trauma and preëxisting infections under the National Research Council of Canada. The object of this investigation has been to determine as far as possible the practical value of bacteriostatics used topically or systemically, both prophylactically and therapeutically, in fresh trauma and preëxisting infections. The work has been done in civilian hospitals, and the laboratories of McGill University. A uniform surgical technique was adapted to the individual case so that the chief variables were the type of bacteriostatic and its method of application. Two types of condition were studied and these were further classified as described below. The accompanying tables carry out this same grouping.

## A—*Fresh Trauma:*

1. Soft-tissue wounds of large size, including avulsion injuries and a few explosive and missile wounds, uncomplicated by injuries to blood vessels, nerves, tendons, joints, *etc.*
2. Wounds complicated by injuries to blood vessels, nerves, tendons, joints, *etc.*
3. Crushed hands and feet.
4. Traumatic amputations of arm and leg.
5. Compound fractures of long bones.
6. Burns—thermal, chemical, brush.
7. Missile wounds of soft-parts.

## B—*Preëxisting Infections*—(all thus far studied have been pyogenic):

1. *Acute spreading* (with or without bacteriemia), such as osteomyelitis, severely infected wounds and burns, and spreading cellulitis of extremities with lymphatic involvement.
2. *Localizing and localized*, such as suppurative tenosynovitis, carbuncles, soft-tissue abscesses, suppurative adenitis, *etc.*
3. *Chronic infections*, such as traumatic osteitis, infected burns, leg ulcers, chronic osteomyelitis, *etc.*

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\* This work was carried out under the auspices of the National Research Council, Ottawa, Canada.

**BACTERIOSTATICS.**—Most attention has been paid to sulfonamides and penicillin. These two materials have been employed both topically and systemically in more or less standardized fashion, as follows:

#### TOPICAL USE

1. *Sulfonamides.*—Sulfathiazole has been employed almost exclusively because of its solubility and relatively wide range of bacteriostatic action. When sensitivity has occurred, sulfadiazine has been substituted. When wounds were closed, sulfathiazole in a 10 per cent watery suspension has been introduced by spray in sufficient quantity to develop a good frosting throughout the wound and the excess allowed to spill over. Where wounds were packed, a 5 per cent oil-in-water emulsion "M. G. H. formula"\* has been universally employed in abundant quantity.

2. *Penicillin.*—Both the calcium and sodium salts have been instilled in powder and solution for closed wounds and in a cream base "N. R. C. formula"† in concentration of 500 to 5,000 units per gram for packing purposes

\* Sulfathiazole Emulsion (M.G.H. formula)

R sulfathiazole	5%
triethanolamine	2%
distilled water	24%
white beeswax	5%
liquid paraffin	64%

† Penicillin Creams (N.R.C. formula)

R Z 2—stearic acid	15%
lanolin	8%
mineral oil	25%
water to	100%
carbitol	5%
R Z 9—stearic acid	10%
cetyl alcohol	5%
spermaceti	8%
lanolin	15%
water to	100%
glycerine	10%

#### SYSTEMIC USE

1. *Sulfonamides.*—While sulfathiazole was used in the early cases, our preference of late has been for sulfadiazine because it is better tolerated by the patients, and is an equivalent antibacteriostatic. The dosage by mouth averaged one gram four times daily, with larger doses the first day. The necessary care in alkalinization and fluid intake has been observed. In a few cases where intravenous therapy has been necessary, a similar dosage has been maintained.

2. *Penicillin.*—Our practice has been to administer a minimum of 100,000 units daily by intravenous or intramuscular routes. The sodium salt has been used exclusively.

Latterly, the scope of the investigation was enlarged to include other materials, such as "BIPP," zinc peroxide, zephiran, certain organic acids, amino-acidines, guanidine HCl, tyrothricin, diasone, etc.

Because of the popular demand for "controls," about a dozen cases were selected at random for surgery without bacteriostatics. Because some of

these cases did not fare so well clinically, it was decided to abandon the practice. The rest of the cases in this sense constitute controls of each other. About 250 cases have been included in this study. An equal number have been treated with similar clinical satisfaction, but insufficient data is available to justify their inclusion in the present discussion.

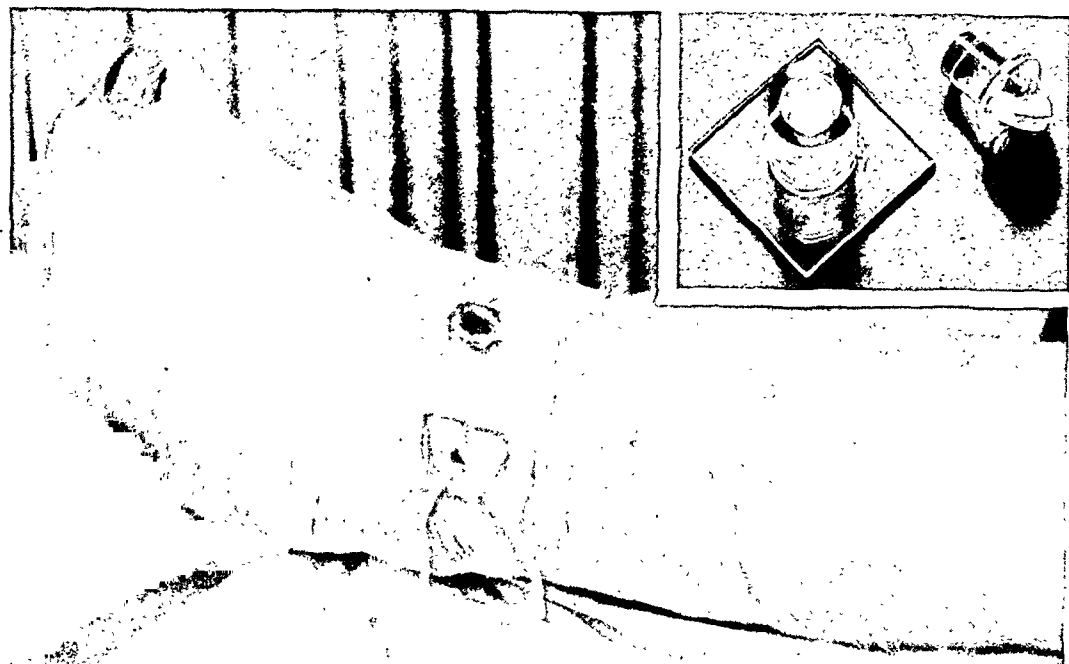


FIG. 1.—Surgical window of "Lucite" or "Perspex."

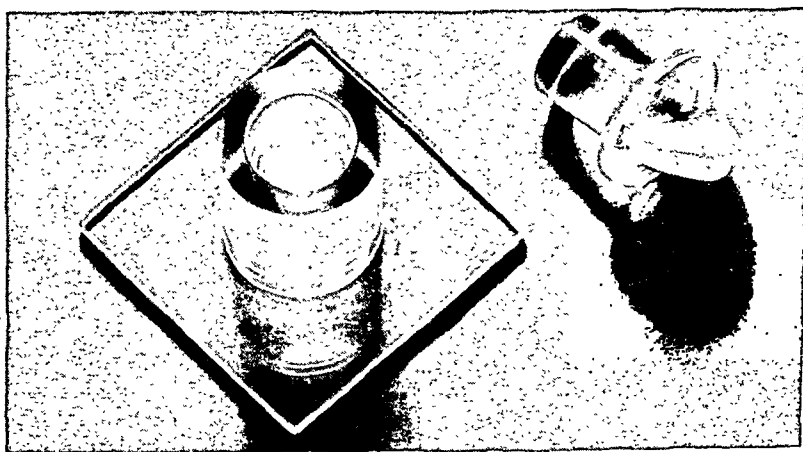


FIG. 2.—Surgical window *in situ*.

Appraisal has been carried out along two coördinated lines: A—Bacteriologic studies. B—Clinical observations.

A—*Bacteriologic studies* were done on all wounds and infections, before surgery, after surgery, and several times weekly through special windows of "Lucite" or "Perspex" (Figs. 1 and 2) and incorporated in the dressings, as well as at dressing changes. This technic has proved entirely satisfactory

as a practical method of acquiring bacteriologic information. We appreciate, as have others, the difficulties inherent in the surgical window technic for cultures. Dressings covering the wound may interfere with easy sampling. Cultures made from the area immediately under the window are not necessarily representative of the wound as a whole. These difficulties are to a large extent resolved, however, by the agreement between the cultures obtained through the window with those at dressing changes. In making cultures, sulfonamides were neutralized by para-amino-benzoic acid and penicillin by penicillinase.

B—*Clinical Observations.*—To facilitate these, a standard method of surgical approach was adopted, which, while observing the best known and approved surgical principles as outlined below, is flexible enough to be adaptable to all forms of trauma and infection met with. It has already been described in the literature,<sup>6</sup> and it will suffice merely to enumerate the principles of the technic:

1. Delay of surgery until shock and hemorrhage are adequately controlled.
2. Surgical asepsis.
3. Preparatory washing with soap and water and copious saline lavage.
4. Adequate timing of initial surgery and subsequent surgical procedures.
5. Adequate surgery—initial and subsequent—including:
  - a. Excision of wound or infection—minimal, partial, maximal, often inadequately referred to as débridement.
  - b. Incision and counter-incision of wound or infection for relief and prevention of tension and for drainage.
  - c. Wound drainage by oily pack, referred to as “curtain drainage.”
  - d. Suturing—*Primary suture* reserved for chest, head, face, joint, nerve and tendon cases.

*Delayed primary* as the general practice except in special cases. This is possible at any time during the first three weeks with revision of the wound.

*Secondary suture* at a later date, implying wound revision because of organizing granulation tissue.

N. B. All suturing was loosely done to prevent tension, with its inevitable risk of edema and danger of local bacterial multiplication.

Primary, delayed primary, and secondary split-skin grafting are terms employed with the same significance as applied to suturing.

6. Bacteriostasis.—From the foregoing, it will be seen that natural bacteriostasis is given full play. It is supplemented by bacteriostatics as innocuous as possible to the reacting tissues, free or fixed.

7. Compression—immobilization by massive occlusive compression dressings of the whole part. The large bulk of cotton waste gives uniformly distributed elastic compression. By this means, the vascular circulation is not impeded and is probably facilitated. Lymph stasis and edema are minimized, while in surface wounds and burns, plasma loss by wound oozing is lessened.

Moreover, the normal mechanism controlling capillary oozing is assisted. Light plaster encasement is added at times for additional immobilization, as in compound fractures of long bones. Internal fixation is done when necessary.

8. Timed infrequent change of dressings. Prevention of secondary infection is the keynote of infrequent dressing changes. This should mean not less than weekly and in long bone fractures at longer intervals, as required for callus formation. Dressings should never be removed for observation purposes. They should only be removed for definite reasons: to wit, for planned surgery, because the wound is healed, or in the rare occurrence of adverse signs and symptoms.

The following tables summarize all pertinent data relating to some 250 cases.

A key to the abbreviations is appended:

wnd.—wound
chr.—chronic
ac.—acute
comp.—compound
S.T.E.—sulfathiazole emulsion
S.D.E.—sulfadiazine emulsion
Pen. Cr.—penicillin cream
C.D.—compression dressing
P.C.D.—plaster-enclosed compression dressing
D.P. suture—delayed primary suture
Sec. suture—secondary suture

#### AMPLIFYING COMMENT

##### A. Fresh Trauma:

1. *Large, uncomplicated soft-tissue wounds (20 cases including four controls):*

Delayed primary suture has been the practice in all of these. The initial surgery included wound excision, irrigation with 10 per cent sulfathiazole suspension, packing with bacteriostatic emulsion, and immobilization with occlusive compression dressing. None of the bacteriostatic-treated cases showed any evidence of clinical infection. There was a tendency for control cases to exhibit some pain, discomfort and fever, and for healing to be delayed up to twice the expected time.

2. *Wounds complicated by nerve, tendon, or joint injury (20 cases—no controls):*

Primary suture after irrigation with the bacteriostatic agent was practiced in all these. During the past year, sulfonamides or penicillin has been given systemically for prophylaxis. This group is the only one in which

primary suture was practiced, and this because it was felt justifiable to obtain the earliest possible function of tendon, nerve or joint, at small risk of infection. This occurred in two cases before prophylactic systemic bacteriostatics were used routinely, and two cases since.

3. *Crushed hands and feet and other complicated injuries (32 cases of crushed hands and feet, including 7 controls):*

The standard practice was delayed primary suture and/or graft with suitable treatment of small bone fractures. Infection occurred in only one control case and this was controlled, in turn, with systemic penicillin. Not a single instance of prolonged neurovascular sequelae was observed.

4. *Traumatic amputation of leg or arm (8 cases—no controls):*

The procedure was identical with No. 3. No infections occurred although in all of them, at one time or another, pyogenic organisms were present.

5. *Compound fractures of long bones (25 cases—no controls):*

Delayed primary or secondary suture was done as indicated after two to six weeks. This was a particularly interesting series without a single wound infection. All were dressed with sulfathiazole emulsion. Attention is drawn to the use of the Stader double-pin splint, incorporated in the first dressing, for better anatomic alignment with marked comminution or other difficulties.

6. *Burns—thermal, chemical, brush (45 cases—no controls):*

All but one were treated with sulfathiazole emulsion and compression dressings. There were 24 superficial and 21 deep burns requiring delayed primary or secondary split-skin grafting. In only a single instance was healing delayed by infection, and this by a preëxisting staphylococcal pyoderma. This was controlled by penicillin intramuscularly. Otherwise there were no infections.

7. *Missile wounds of soft-parts (8 cases—no controls):*

The usual practice was followed. Three buttock wounds showed some delay in healing from *B. proteus vulgaris* infections.

B. *Preëxisting Infections:*

1. *Acute spreading, with or without bacteriemia (no controls). (32 cases including acute osteomyelitis; spreading cellulitis; neglected burns; and suppurative tenosynovitis):*

Systemic bacteriostatics were employed until localization. All cases were then treated by incision and packing with a bacteriostatic agent and, when expedient, sutured or grafted after two to four weeks. Bacteriemia was treated by suitable systemic bacteriostatics as, for example, Cases 2 and 27 in Table B-1. Acute staphylococcal infections received penicillin intravenously and intramuscularly with equal success as, for example, Cases 14 and 18 in Table B-1. This group also included seven badly infected neglected burns, all of which were cured by topical application of sulfathiazole emulsion and one dressing.



TABLE A - 1

FRESH TRAUMA

-

## LARGE UNCOMPLICATED SOFT TISSUE WOUNDS

NO.	TYPE OF INJURY	PRIMARY SURGERY	BACTERIO- STATIC	TYPE OF DRESSING	INITIAL PATHOGENS	FATE OF SAME	SUBSEQUENT SURGERY	NEW PA- THOGENS	FATE OF SAME	CLINICAL RESULTS
1.	LARGE AVULSION WOUND ARM	MAX. WOUND EXCISION PACK	CONTROL BASE	P.C.D.	STAPH. PYOGENES O. WELCHII	PERSIST IST CULTURE ONLY	D.P. SUTURE 11TH DAY	NONE		MORE THAN USUAL FEVER AND PAIN 100% TAKE OF GRAFT. HEALED AT 5 WEEKS
2.	SEVERE LACERATION THIGH	MIN. WOUND EXCISION PACK	"	P.C.D.	STAPH. PYOGENES	DISAPPEAR GRADUALLY	D.P. SUTURE 15TH DAY	NONE		HEALED AT 4 WEEKS
3.	DEEP ERYE WHEEL CUT THIGH	NONE	"	C.D.	NONE		DEFECT ALLOWED TO GRANULATE & FILL. SEC. SPLIT SKIN GRAFT AT 35 DAYS	NONE		HEALED AT 7 WEEKS
4.	LARGE SOFT TISSUE WOUNDS LEFT LEG	MIN. WOUND EXCISION PACK	S.T.E.	P.C.D.	STAPH. PYOGENES	PERSIST	D.P. SUTURE ON 14TH DAY	NONE		HEALED AT 4 WEEKS
5.	SEVERE SCALP LACERATION WITH LOSS OF LARGE FLAP	PARTIAL CLOSURE BY PLASTIC REPAIR SLIDING SCALP PACK	S.T.E.	P.C.D.	NONE		D.P. SUTURE ON 14TH DAY SLIDING SCALP. SEC. GRAFT 35TH DAY. FINAL EXCISION & REPAIR 65TH DAY.	NONE		HEALED AFTER EACH OPERATION RAPIDLY AND COMPLETE AT 10TH WEEK
6.	AVULSION INJURY DORSUM HAND WRINGER INJURY	MIN. WOUND EXCISION PARTIAL PRIMARY SUTURE AND COVER TENDONS. PACK	S.T.E.	P.C.D.	NONE		D.P. SUTURE TO COMPLETE ON 16TH DAY	STAPH. PYOS.	PERSIST	HEALED AT 5 WEEKS FUNCTION AT 7 WEEKS
7.	SEVERE LACERATION OF SCALP WITH LOSS OF TISSUE	PRIMARY SUTURE ALL BUT SHALL AREA	S.T.E.	C.D.	NONE		NONE RE-DRESSED AT 1 WEEK	NONE		HEALED AT 10 DAYS.
8.	STAB WOUND OF FOREARM	MIN. WND. EXCISION PACK	S.T.E.	C.D.	WELCHII	PERSIST	NONE	NONE		HEALED AT 10 DAYS
9.	MULTIPLE SOFT TISSUE WND LEFT LEG	PARTIAL WND. EXCISION PACK	S.T.E.	P.C.D.	NONE		D.P. SUTURE 16TH DAY	STAPH. PYOS. ON 10TH DAY ONE CUL- TURE		HEALED AT 4 WEEKS
10.	STAB WOUND OF ARM	WOUND EXCISION PACK	S.T.E.	C.D.	NONE		D.P. SUTURE AT 8 DAYS	NONE		HEALED AT 18 DAYS
11.	LACERATION OF LEG	WOUND EXCISION PACK	S.T.E.	C.D.	NONE		D.P. SUTURE AT 6 DAYS	STAPH. PYOS.	PERSIST	HEALED AT 20 DAYS
12.	STAB WOUNDS ARM AND CHEST	WOUND EXCISION PACK	S.T.E.	C.D.	NONE		D.P. SUTURE AT 7 DAYS	NONE		HEALED AT 18 DAYS
13.	LACERATION LEFT THIGH	WOUND EXCISION PACK	PEN. CR.	C.D.	STAPH. PYOGENES	PERSIST	D.P. SUTURE AT 10 DAYS	NONE		HEALED AT 18 DAYS
14.	LACERATION RIGHT ARM	WOUND EXCISION PACK	PEN. CR.	C.D.	NONE		D.P. SUTURE AT 4 DAYS	STAPH. PYOS.	PERSIST	HEALED AT 14 DAYS
15.	LARGE HAEMATOMA THIGH FROM CRUSH INJURY	EVACUATION HAEMATOMA INCI- SION & EXCISION PACK	S.T.E.	C.D.	NONE		D.P. SUTURE AT 10 DAYS	NONE		HEALED AT 20 DAYS
16.	LARGE LACERATIONS BOTH LEGS	WOUND EXCISION PACK	S.T.E.	C.D.	STAPH. PYOGENES	PERSIST	D.P. SUTURE AT 10 DAYS	NONE		HEALING DELAYED BY INFECTION 30 DAYS - MYCODEMA
17.	MULTIPLE SOFT TISSUE WND. LEFT LEG	WOUND EXCISION PACK	S.T.E.	C.D.	NONE		D.P. SUTURE AT 14 DAYS	STAPH. PYOS.	PERSIST	HEALED AT 28 DAYS
18.	LARGE HAEMATOMA, HIP	WOUND INCISION & EXCISION	S.T.E.	C.D.	NONE		D.P. SUTURE AT 12 DAYS	NONE		HEALED AT 21 DAYS
19.	STAB WND BUTTOCK WITH HAEMATOMA	EVACUATION OF HAEMATOMA EXCISION	S.T.E.	C.D.	PROTEUS		D.P. SUTURE AT 10 DAYS	NONE		HEALING DELAYED 4 WEEKS
20.	LACERATION EVULSION LEG	WOUND EXC. PACK	CONTROL BASE	C.D.	PROTEUS		D.P. SUTURE AT 7 DAYS	STAPH. PYOS.	PERSIST	HEALING DELAYED 6 WEEKS

**FRESH TRAUMA - WOUNDS COMPLICATED BY NERVE, TENDON AND JOINT INJURIES**

**TABLE A - 2**

NO.	TYPE OF INJURY	PRIMARY SURGERY	BACTERIO- STATIC	TYPE OF DRESSING	INITIAL PATHOGENS	FATE OF SAFE	SUBSEQUENT SURGERY	NEW PA- THOGENS	FATE OF SAFE	CLINICAL RESULTS
1.	LACERATION HAND DIVULSION FLEX. TENDONS	PRIM. SUTURE	SULFA SUSP.	P.C.D.	NONE		NONE	NONE		HEALED IN 3 WEEKS GOOD FUNCTION
2.	LACERATIONS WRIST, DIVULSION FLEX. TENDONS	PRIM. SUTURE	SULFA SUSP.	P.C.D.	NONE		NONE	NONE		HEALED AT 4 WEEKS FUNCTION AT 6 WEEK
3.	MULTI-LACERATIONS HAND & FINGERS DIVULSION 2 FLEX. TENDONS	PRIM. SUTURE TENDONS WOUND PACKED	SULFA SUSP. S.T.E.	P.C.D.			D.P. SUTURE WOUND AT 14 DAYS	NONE		HEALED AT 4 WEEKS FUNCTION AT 6 WEEK
4.	LACERATIONS HAND AND ARM MULT. TENDON DIVULSION	PRIM. SUTURE TENDONS WOUND PACKED	S.T.E.	P.C.D.	NONE		D.P. SUTURE AT 18 DAYS	NONE		HEALED AT 4 WEEKS FUNCTION AT 5 WEEK
5.	LACERATIONS HAND DIVULSION EXT. TENDONS	PRIM. SUTURE TENDONS AND WOUND	SULFA SUSP.	P.C.D.	NONE		NONE	NONE		HEALED AT 3 WEEKS FUNCTION AT 6 WEEK
6.	LACERATIONS FINGERS, DIVUL- SION 1 FLEX. TENDON	PRIM. SUTURE TENDON AND WOUND	SULFA SUSP.	P.C.D.	STAPH. PYOG. I CULTURE		NONE	NONE		HEALED AT 3 WEEKS GOOD FUNCTION
7.	LACERATIONS FINGERS, DIVULSION 1 FLEX. TENDON	PRIM. SUTURE TENDON AND WOUND	SULFA SUSP.	P.C.D.	NONE		NONE	NONE		HEALED AT 3 WEEKS GOOD FUNCTION
8.	LACERATIONS FINGER DIVULSION 1 FLEX. TENDON	PRIM. SUTURE TENDON AND WOUND	SULFA SUSP.	P.C.D.	NONE		NONE	NONE		HEALED AT 3 WEEKS GOOD FUNCTION
9.	LACERATION OF HAND, DIVULSION 1 FLEX. TENDON	PRIM. SUTURE	SULFA SUSP.	P.C.D.	STAPH. PYOG. I CULTURE		NONE	NONE		HEALED AT 3 WEEKS
10.	LACERATION FOREARM, DI- VULSION FLEX. TENDONS AND MEDIAN NERVE	WOUND EXCISION PRIMARY SUTURE	SULFA SUSP.	P.C.D.	NONE		NONE	NONE		HEALED AT 3 WEEKS GOOD FUNCTIONAL RECOVERY NERVE AND TENDON
11.	LACERATIONS FINGERS DIVUL- SION FLEX. TENDONS	WOUND EXCISION PRIMARY SUTURE	SULFA SUSP.	P.C.D.	NONE		NONE	NONE		HEALED AT 3 WEEKS
12.	LACERATIONS HAND DIVULSION FLEX. TENDONS FINGER	WOUND EXCISION PRIMARY SUTURE	SULFA SUSP.	P.C.D.	STAPH. PYOG.	PERSIST	NONE	NONE		HEALED AT 3 WEEKS
13.	LACERATION FINGERS DIVUL- SION FLEX. TENDONS	WOUND EXCISION PRIMARY SUTURE	SULFA SUSP.	P.C.D.	STAPH. PYOG.	PERSIST	INFECTION WOUND RE-OPENED AT 5 DAYS. PACKED WITH S.T.E.SEC. SUTURE 3 WEEKS	AT OPER. STAPH. PYOG.	PERSIST	HEALING AFTER 6 WEEKS FUNCTION IMPAIRED
14.	LACERATION FINGERS DIVUL- SION FLEX. TENDONS	WOUND EXCISION PRIMARY SUTURE	SULFA SUSP.	P.C.D.	NONE		INFECTION WOUND RE-OPENED AND PACKED AT 6 DAYS WITH S.T.E.	STAPH. PYOG.	PERSIST	HEALING AFTER 6 WEEKS FUNCTION IMPAIRED
15.	LACERATIONS HAND DIVULSION EXT. TENDONS	WOUND EXCISION PRIMARY SUTURE	SULFA SUSP. SULFA ORALLY	P.C.D.	NONE		WOUND RE-OPENED AND PACKED AT 6 DAYS WITH S.T.E. S.E.C. SUTURE 4 WEEKS	STAPH. PYOG.	PERSIST	HEALING AFTER 6 WEEKS FUNCTION IMPAIRED
16.	FLEX. TENDONS FOREARM - LARGE LACERATIONS	WOUND EXCISION PRIMARY SUTURE	"	P.C.D.	NONE		NONE	NONE		HEALING AT 3 WEEKS
17.	LACERATIONS HAND DIVULSION FLEX. TENDONS	WOUND EXCISION PRIMARY SUTURE	"	P.C.D.	STAPH. PYOG. I CULTURE		NONE	NONE		HEALING AT 3 WEEKS
18.	LACERATION HAND DIVULSION TENDON	PRIMARY SUTURE	SULFA SUSP. PEN. INTRAM AFTER INFECTION	P.C.D.	NONE		WOUND INFECTION, OPENED AT 10 DAYS PACKED OSTEOITIS OF PHALANX	STAPH. PYOG.	PERSIST	DELAY IN HEALING 2 MONTHS POOR FUNCTION

TABLE A - 2 - FRESH TRAUMA - WOUNDS COMPLICATED BY NERVS, TENDON AND JOINT INJURIES

NO.	TYPE OF INJURY	PRIMARY SURGERY	BACTERIO-STATIC	TYPE OF DRESSING	INITIAL PATHOGENS	FATE OF SAFE	SUBSEQUENT SURGERY	NEW PATHOGENS	FATE OF SAFE	CLINICAL RESULTS
19.	COMP. WOUND INTO KNEE JOINT	WOUND EXCISION PRIMARY SUTURE JOINT WOUND PACKED	SULFA SUSP. SULFA ORALLY	P.C.D.	NONE		D.P. SUTURE AT 21 DAYS	NONE		HEALED AT 30 DAYS
20.	LACERATION OF FOREARM FLEX. TENDONS & MEDIAN NERVE DIVULSED	WOUND EXCISION PRIMARY SUTURE NERVE, TENDONS WOUND	SULFA SUSP. SULFA ORALLY	P.C.D.	STAPH. PYOG.	PERSIST	NONE	NONE		HEALED AT 3 WEEKS EXCELLENT NER AND TENDON FUNCTIONAL RECOVERY

TABLE A - 3 - FRESH TRAUMA - CRUSH HANDS & FEET

NO.	TYPE OF INJURY	PRIMARY SURGERY	BACTERIO-STATIC	TYPE OF DRESSING	INITIAL PATHOGENS	FATE OF SAFE	SUBSEQUENT SURGERY	NEW PATHOGENS	FATE OF SAFE	CLINICAL RESULTS
1.	CRUSH FOOT-DEEP SPLIT WOUND	MIN. WND. EXCISION PACK	CONTROL BASE	P.C.D.	PTOXYA-MEUS	PERSIST	D.P. SUTURE 14TH DAY	NONE		HEALED AT 5 WKS
2.	CRUSH HAND. AMPUTATION ALL FOUR FINGERS	RE-AMP. DISARTICULATION AT METACARPAL. JOINTS PACK	" "	P.C.D.	STAPH. PYOG.	DISAPPEAR GRADUALLY	D.P. SUTURE 15TH DAY	NONE		MORE PAIN AND FEVER THAN USUAL HEALED AT 9 WEEKS.
3.	CRUSH HAND. COMP. FRACT. 1ST METACARPAL. TENDON DIVULSED	PARTIAL WOUND EXCISION, REDUCTION, PACK	S.T.E.	P.C.D.	"	PERSIST	D.P. SUTURE 15TH DAY	NONE		HEALED AT 4 WEEKS FUNCTION AT 5 WEEKS
4.	CRUSH FOOT AMP. HALLUX	RE-AMP. PACK	S.T.E.	P.C.D.	WELCHII	PERSIST	D.P. SUTURE 20TH DAY	NONE		HEALED AT 6 WEEKS
5.	CRUSH HAND, PARTIAL AMP. 2 FINGERS	RE-AMP. PACK	S.T.E.	P.C.D.	NONE		D.P. SUTURE 14TH DAY	STAPH. PYOG.	PERSIST	HEALED AT 5 WEEKS FUNCTION AT 7 WEEKS
6.	SEVERE CRUSH HAND AND FINGERS PARTIAL AMP. OF 2 FINGERS	RE-AMP. FINGERS. PACK. HIM.	S.T.E.	P.C.D.	NONE		D.P. GRAFT AND SUTURE 16TH DAY	NONE		HEALED AT 5 WEEKS FUNCTION OF FOREFINGER IS POOR AT 8 WEEKS
7.	SEVERE CRUSH HAND DIVULSED TENDON	MIN. WND. EXCISION. PRIM. SUTURE, TENDON AND FINGER	S.T.E.	P.C.D.	NONE		D.P. GRAFT AND SUTURE 14TH DAY	NONE		HEALED AT 4 WEEKS
8.	CRUSH FOOT. LARGE SOFT TISSUE LACERATION SOLE. COMP. FRACTURE GREAT TOE	MIN. WND. EXCISION PACKS	PROFLA-VINE	P.C.D.	NONE		D.P. SUTURE 30TH DAY UNPAIDDED WALKING P.P.C. 48TH DAY	STAPH. PYOG.	PERSIST	HEALED AT 6 WEEKS FUNCTION AT 1 WEEKS
9.	CRUSH HAND, COMP. FRACTURE FOREFINGER	MIN. WND. EXCISION PACK	B.I.P.P.	P.C.D.	STAPH. PYOG.	DISAPPEAR GRADUALLY	D.P. SUTURE 14TH DAY	NONE		HEALED AT 4 WEEKS FUNCTION AT 6 WEEKS
10.	CRUSH HAND. PARTIAL AMP. OF TWO FINGERS	RE-AMP. PARTIAL WOUND EXCISION. PACK	PEN. CR.	P.C.D.	NONE		D.P. SUTURE AND GRAFT 14TH DAY	NONE		HEALED AT 4 WEEKS FUNCTION AT 6 WEEKS
11.	CRUSH HAND. COMP. FRACTURE ALL FOUR METACARPALS DESTRUCTION 4 TENDONS	PARTIAL WOUND EXCISION	PEN. CR.	P.C.D.	NONE		D.P. GRAFT 21ST DAY REPAIR TENDONS 42ND DAY	STAPH. PYOG.	PERSIST	HEALED AFTER BOTH OPER. GRAFT TOOK TAKE FUNCTION PARTIAL AT 1 MONTHS
12.	CRUSH FOOT COMP. FRACTURE TARSAL BONES. 2 LARGE WINDS	MIN. WND. EXCISION REDUCTION - PACK	PEN. CR.	P.C.D.	NONE		D.P. SUTURE 14TH DAY. MOULDED UNPAIDDED WALKING P.P.C. ON 28TH DAY	NONE		HEALED AT 4 WEEKS FUNCTION AT 4 MONTHS
13.	CRUSH HAND. PARTIAL AMP. LEFT HAND	RE-AMP. LEFT THUMB METACARPAL JOINT PACK	PEN. CR.	P.C.D.	STAPH. PYOG.	PERSIST	D.P. SUTURE ON 14TH DAY	NONE		HEALED AT 4 WEEKS TO HAVE PLAST
14.	CRUSH HAND. COMP. FRACTURE SOFT TISSUE WINDS. 3 FINGERS	RE-AMP. PACK	PEN. CR.	P.C.D.	NONE		D.P. SUTURE AND GRAFT 14TH DAY	STAPH. PYOG.	PERSIST	HEALED AT 4 WEEKS FUNCTION AT 4 WEEKS
15.	CRUSH FOOT COMP. FRACTURE PROX. PHALANX GREAT TOE	MIN. WND. EXCISION REDUCTION PACK	PEN. CR.	P.C.D.	STAPH. PYOG.	DISAPPEAR	D.P. SUTURE 14TH DAY	NONE		HEALED AT 4 WEEKS WALKING P.P.C. UNPAIDDED

TABLE A - 3

## FRESH TRAUMA - CRUSH HANDS &amp; FEET

NO.	TYPE OF INJURY	PRIMARY SURGERY	BACTERIO- STATIC	TYPE OF DRESSING	INITIAL PATHO- GENS	FATE OF SAME	SUBSEQUENT SURGERY	NEW PA- THOGENS	FATE OF SAME	CLINICAL RESULTS
16.	CRUSH FOOT PARTIAL AMP.	RE-AMP. PACK	S.T.E.	P.C.D.	NONE		RE-AMP. AND D.P. SUTURE AT 14 DAYS	NONE		HEALED AT 3 WEEKS FUNCTION AT 5 WEEKS
17.	CRUSH HAND AMP. OF FINGER	RE-AMP. OF FINGER	S.T.E.	P.C.D.	STAPH. PYOG.	PERSIST	D.P. SUTURE AT 10 DAYS	NONE		HEALED AT 2 WEEKS FUNCTION AT 4 WEEKS.
18.	CRUSH HAND, PARTIAL AMP. OF THUMB	EXCISION RE-AMP. THUMB. PACK	S.T.E.	C.D.	STAPH. PYOG.	PERSIST	D.P. SUTURE AND GRAFT AT 12 DAYS	NONE		HEALED AT 3 WEEKS TO HAVE PLASTIC RECONSTRUCT.
19.	CRUSH HAND, ROLLER INJURY DORSAL FLAP	PARTIAL EXCISION PART. SUTURE	S.T.E.	C.D.	"	PERSIST	D.P. SUTURE AT 14 DAYS	NONE		HEALED COMPLETELY 28 DAYS NORMAL FUNCTION 6 WEEKS
20.	CRUSH HAND WITH COMP. FRACT. 1ST AND 2ND FINGERS	WND. EXCISION PARTIAL RE-AMP. PACK	S.T.E.	P.C.D.	"	PERSIST	D.P. SUTURE AT 1 WEEK	NONE		HEALED AT 2 WEEKS - FUNCTION AT 6 WEEKS
21.	CRUSH HAND, WITH COMP. FRACT. THUMB AND SEVERE LONG FLEX. TENDON	WND. EXCISION TENDON SUTURE PACK	S.T.E.	P.C.D.	NONE		D.P. SUTURE-AT 10 DAYS	NONE		HEALED AT 21 DAYS - FUNCTION AT 6 WEEKS
22.	CRUSH HAND, AMP. FOREFINGER	DISARTICULATE FINGER PACK	S.T.E.	P.C.D.	NONE		D.P. SUTURE AT 5 DAYS	STAPH. PYOG.	PERSIST	HEALED AT 18 DAYS - FUNCTION AT 4 WEEKS
23.	CRUSH HAND, PARTIAL AMP. FOREFINGER	RE-AMP. FINGER PACK	S.T.E.	C.D.	STAPH. PYOG.	DISAPPEAR IN 4 DAYS	D.P. SUTURE AT 4 DAYS			HEALED AT 19 DAYS - FUNCTION AT 5 WEEKS
24.	CRUSH HAND, PARTIAL AMP. FOREFINGER	RE-AMP. FINGER PACK	S.T.E.	C.D.	STAPH. PYOG.	PERSIST	D.P. SUTURE AT 5 DAYS	NONE		HEALED AT 10 DAYS - FUNCTION AT 4 WEEKS
25.	CRUSH HAND, SEVERE AMP. FOUR FINGERS	RE-AMP. PACK	S.T.E.	P.C.D.	"	PERSIST	D.P. SUTURE AT 8 DAYS	NONE		HEALED AT 3 WEEKS - FUNCTION AT 6 WEEKS
26.	CRUSH FOOT AND LEG	EXCISION PACK	CONTROL BASE	P.C.D.	"	PERSIST	D.P. SUTURE AT 7 DAYS	NONE		DELAY IN HEALING & REQUIRED 3RD R DRESSING AT 17 DAYS HEALED AT 31 DAYS - FUNCTION AT 2 MONTHS
27.	CRUSH HAND AND WRIST LACERATIONS PALM PART. AMP. 4TH FINGER	EXCISION RE-AMP. FINGER. PACK	CONTROL BASE	P.C.D.	NONE		D.P. SUTURE AT 6 DAYS	STAPH. PYOG.	PERSIST	HEALED AT 20 DAYS FUNCTION AT 4 WEEKS
28.	CRUSH HAND PARTIAL AMP. 3RD, 4TH AND 5TH FINGERS	EXCISION RE-AMP. PACK	CONTROL BASE	C.D.	NONE		D.P. SUTURE AT 4 DAYS	NONE		HEALED AT 16 DAYS - FUNCTION AT 3 WEEKS
29.	CRUSH HAND. AVULSION COMP. FRACTURE 4 METACARPALS	EXCISION PACK. PENICILLIN INTRAMUSC.	CONTROL BASE	P.C.D.	STAPH. PYOG. WELCHII	PERSIST PERSIST	D.P. SUTURE AND GRAFT 6 DAYS	STAPH. INFECTION		DEVELOPED SPREADING INFECTION IN HAND WITH STAPH. DELAY IN HEALING REQ. PENICILLIN 1 WEEK
30.	CRUSH HAND. COMP. FRACTURE 4 METACARPALS PARTIAL TENDONS DIVULSION	EXCISION PACK.	S.T.E.	P.C.D.	NONE		D.P. GRAFT 12 DAYS	STAPH. PYOG.	PERSIST	HEALED AT 4 WEEKS - FUNCTION AT 6 MONTHS
31.	CRUSH HAND. G.C.P. FRACTURE THUMB & METACARPAL	EXCISION PACK	S.T.E.	P.C.D.	STAPH. PYOG.	PERSIST	D.P. SUTURE 14 DAYS	NONE		HEALED AT 3 WEEKS - FUNCTION AT 5 WEEKS
32.	CRUSH HAND. COMP. FRACTURE THUMB	EXCISION PACK	CONTROL BASE	P.C.D.	STAPH. PYOG.	PERSIST	D.P. SUTURE 12 DAYS	NONE		HEALED AT 4 WEEKS - FUNCTION AT 7 WEEKS

TABLE A - 4

## FRESH TRAUMA

## AMPUTATIONS - TRAUMATIC

NO.	TYPE OF INJURY	PRIMARY SURGERY	BACTERIO- STATIC	TYPE OF DRESSINGS	INITIAL PATHO- GENS	FATE OF SAVE	SUBSEQUENT SURGERY	NEW PA- THOGENS	FATE OF SAVE	CLINICAL RESULTS
1.	TRAIN ACCIDENT. AMPUTATION BOTH LEGS IN MIDDLE THIRD. SEVERE HAEMORRHAGE AND SHOCK	AFTER 6 HOURS ANTI-SHOCK TREATMENT. OPEN RE-AMP. 3" BELOW KNEE. PACK.	S.T.E.	P.C.D. SPICA	NONE		D.P. SUTURE & GRAFT 19TH DAY	STAPH. PYOG.	PERSIST	HEALED AT 5 WEEKS - FUNCTION WITH PROTHESIS AT 4 MONTHS
2.	LARGE AVULSION WND. THIGH AND LEG DES- TROYS FEMORAL VESSELS. SEVERE HAEMORRHAGE AND SHOCK	AFTER 6 HOURS ANTI-SHOCK TREATMENT LIGATION VESSELS ONLY. AFTER 48 HOURS WND. EXCISION. OPEN RE-AMP. LOWER 1/3 THIGH	S.T.E. S.T.E.	P.C.D. P.C.D. SPICA	STAPH. PYOG.	PERSIST	D.P. SUTURE & GRAFT 18TH DAY	NONE		HEALED AT 4 WEEKS - FUNCTION WITH PROTHESIS AT 4 MONTHS
3.	MACHINE CRUSH LOWER LEG AND ANKLE COMPOUNDING JOINT. MODERATE HAEMORRHAGE AND SHOCK	AFTER 6 HOURS ANTI-SHOCK TREATMENT. WND. EXCISION OPEN RE-AMP. LEG. PACK	S.T.E.	P.C.D.	STAPH. PYOG. COLI	PERSIST PERSIST	D.P. SUTURE 17TH DAY	NONE		HEALED AT 1 WEEKS - FUNCTION WITH PROTHESIS AT 10 WEEKS
4.	TRAIN ACCIDENT. AMPUTATING LEG IN LOWER 1/3. SEVERE HAEMORRHAGE AND SHOCK	AFTER 7 HOURS ANTI-SHOCK TREATMENT. WND EXCISION OPEN RE-AMP. LEG. PACK	S.T.E.	P.C.D.	STAPH. PYOG.	PERSIST	D.P. SUTURE 18 DAYS	NONE		HEALED AT 4 WEEKS - FUNCTION WITH PROTHESIS AT 8 WEEKS
5.	MACHINE CRUSH WITH COMPOUND FRACTURE, DISLOCATION LOWER 1/2 OF LEG AND ANKLE. SEVERE HAEMORRHAGE AND SHOCK	AFTER 8 HOURS ANTI-SHOCK TREATMENT, WND EXCISION OPEN RE-AMP. LEG. PACK	S.T.E.	P.C.D.	STAPH. PYOG. PROTEUS	PERSIST DISAPPEAR 10TH DAY	D.P. SUTURE 19TH DAY	NONE		HEALED AT 5 WEEKS - FUNCTION WITH PROTHESIS AT 10 WEEKS
6.	MACHINE CRUSH HAND AND WRIST. MOD. HAEMORRHAGE AND SHOCK	AFTER 6 HOURS ANTI-SHOCK TREATMENT. WND EXCISION OPEN RE-AMP. FOREARM	PEN. CR.	P.C.D.	STAPH. PYOG.	PERSIST	D.P. SUTURE 12TH DAY	NONE		HEALED AT 3 WEEKS - FUNCTION WITH VESSLER PROTHESIS - IN PROCESS
7.	MOTORCYCLE ACCIDENT INVOLVING LOWER LEG AND ANKLE IN COMP. FRACTURES. MOD. HAEMORRHAGE AND SHOCK	AFTER 8 HOURS ANTI-SHOCK TREATMENT. WND EXCISION OPEN RE-AMP. LEG. PACK	S.T.E.	P.C.D.	STREP. PYOG. A DISAPPEAR COLI	DISAPPEAR 3RD DAY DISAPPEAR 12TH DAY	D.P. SUTURE 20TH DAY	STAPH. PYOG.	PERSIST	HEALED AT 5 WEEKS - FUNCTION AT 3 MONTHS WITH PROTHESIS
8.	LARGE AVULSION WND. LEG WITH DESTRU- TION OF CIRCULATION AND ANKLE JOINT MOD. HAEMORRHAGE AND SHOCK	AFTER 4 HOURS ANTI-SHOCK TREATMENT OPEN RE-AMP. AT SITE OF ELECTION	S.T.E.	P.C.D.	NONE		D.P. SUTURE 18 TH DAY	"	PERSIST	HEALED AT 4 WEEKS - FUNCTION WITH PROTHESIS AT 3 MONTHS

TABLE A - 5

## FRESH TRAUMA

## COMPOUND FRACTURES - ARM AND LEG

NO.	TYPE OF INJURY	PRIMARY SURGERY	BACTERIO- STATIC	TYPE OF DRESSINGS	INITIAL PATHOGENS	FATE OF SAVE	SUBSEQUENT SURGERY	NEW PA- THOGENS	FATE OF SAVE	CLINICAL RESULTS
1.	BOTH BONES RT. LEG SOFT TISSUE WND. LT. INTERNAL INJURIES. FRACT. RIBS, PELVIS, RADIUS, CLAVICLE	WND. EXCISION REDUCTION PACK	S.T.E.	P.C.D.	LEFT LEG PYOCYANUS 3RD RT. LEG NONE	DISAP. 3RD DAY	D.P. SUTURE 16 DAYS	LT. STAPH PYOG. RT. "	PERSIST PERSIST	HEALED AT 4 WEEKS. THEN UNPAIDED CAST - FUNCTION A 7 1/2 MONTHS
2.	RIGHT HUMERUS	PARTIAL EXCISION. REDUCTION PACK	S.T.E.	P.C.D.	NONE	NONE	SEC. SUTURE 4 WEEKS	NONE		HEALED AT 6 WEEKS - FUNCTI AT 3 MONTHS
3.	BOTH BONES RT. LEG. SOFT TISSUE WND. LT.	PARTIAL EXCISION. REDUCTION PACK	S.T.E.	P.C.D.	STAPH. PYOG. RT. LT.	PERSIST DISAPPEAR	SEC. SUTURE 4 WEEKS	NONE		HEALED AT 6 WEEKS - FUNCTI AT 5 MONTHS
4.	BOTH BONES LT. LEG	MIN. EXCISION	S.T.E.	P.C.D.	NONE	NONE	D.P. SUTURE 16 DAYS	STAPH. PYOG.	PERSIST	HEALED AT 4 WEEKS - FUNCTI AT 6 MONTHS

TABLE A - 5

FRESH TRAUMA

COMPOUND FRACTURES - ARM AND LEG \*

NO.	DIAGNOSIS	PRIMARY SURGERY	BACTERIO- STATIC	TYPE OF DRESSING	INITIAL PATHOGENS	FATE OF SAFE	SUBSEQUENT SURGERY	NEW PA- THOGENS	FATE OF SAFE	CLINICAL RESULTS
5.	BOTH BONES LEFT FOREARM LARGE SOFT TISSUE WOUNDS AND DESTRUCTION MUSCLE AND TENDONS	EXTENSIVE WND EXCISION REDUCTION PACK	S.T.E.	P.C.D.	STREP. VIR.	PERSIST 4 WEEKS	SEC. SUTURE AND SPLIT GRAFT, 6 WEEKS	NONE		HEALED AT 9 WEEKS - FUNCTION AT 6 MONTHS
6.	BOTH BONES RIGHT FOREARM LARGE SOFT TISSUE WND AND DESTRUCTION MUSCLE AND TENDONS	EXTENSIVE WND EXCISION REDUCTION PACK	S.T.E.	P.C.D.	NONE		SEC. SUTURE AND SPLIT GRAFT 4 WEEKS	STAPH. PYOG.	PERSIST	HEALED AT 6 WEEKS - FUNCTION AT 6 MONTHS
7.	BOTH BONES LEFT LEG	PARTIAL WOUND EXCISION PACK	S.T.E.	P.C.D.	NONE		D.P. SUTURE AT 17TH DAY	NONE		HEALED AT 6 WEEKS - FUNCTION AT 6 MONTHS
8.	BOTH BONES RIGHT LEG xx	WHD EXCISION STADER SPLINT IN DRESSING	S.T.E.	P.C.D.	STAPH. PYOG.	PERSIST	D.P. SUTURE 14TH DAY	NONE		HEALED AT 6 WEEKS - FUNCTION AT 7 MONTHS
9.	BOTH BONES RIGHT FOREARM xx	EXTENSIVE WND EXCISION STADER SPLINT IN DRESSING	S.T.E.	P.C.D.	STAPH. PYOG.	PERSIST	D.P. SUTURE 20TH DAY	STAPH PYOG.	PERSIST	HEALED AT 4 WEEKS - FUNCTION AT 6 MONTHS
10.	BOTH BONES LEFT LEG	PARTIAL WND EXCISION PACK	S.T.E.	P.C.D.	NONE		D.P. SUTURE 14TH DAY	STAPH PYOG.	PERSIST	HEALED AT 5 WEEKS - FUNCTION AT 7 1/2 MONTHS
11.	BOTH BONES RIGHT LEG	MIN. WND EXCISION PACK	S.T.E.	P.C.D.	NONE		D.P. SUTURE 14TH DAY	NONE		HEALED AT 4 WEEKS - FUNCTION AT 8 MONTHS
12.	BOTH BONES LEFT LEG. LOSS OF xx EXT. TENDONS	EXTENSIVE WND. EXCISION PACK	S.T.E.	P.C.D.	PROTEUS STAPH. PYOG.	PERSIST	D.P. SUTURE 18TH DAY	NONE		HEALED AT 4 WEEKS - FUNCTION AT 6 MONTHS
13.	BOTH BONES RT. LEG xx	WHD. EXCISION PACK	S.T.E.	P.C.D.	NONE		D.P. SUTURE 17TH DAY	NONE		HEALED AT 4 WEEKS - FUNCTION AT 6 MONTHS
14.	BOTH BONES RT. FOREARM	WHD EXCISION PACK	S.T.E.	P.C.D.	NONE		D.P. SUTURE 21ST DAY	NONE		HEALED AT 4 WEEKS - FUNCTION AT 6 MONTHS
15.	BOTH BONES RT. LEG. LARGE SOFT TISSUE WND	EXTENSIVE WND EXCISION REDUCTION PACK	S.T.E.	P.C.D.	STAPH. PYOG.	PERSIST	D.P. SUTURE 21ST DAY	STAPH. PYOG.	PERSIST	HEALED AT 4 WEEKS - FUNCTION AT 6 MONTHS (CHILD)
16.	RT. HUMERUS INTO ELBOW JOINT xx LARGE SOFT TISSUE WOUND	IMPOSSIBLE TO CLOSE JOINT WHD EXC. RED. PACK	S.T.E.	P.C.D.	STAPH. PYOG.	PERSIST	SEC. SUTURE 28TH DAY	NONE		HEALED AT 5 WEEKS - FUNCTION AT 3 MONTHS (CHILD)
17.	BOTH BONES LEFT LEG	WHD EXCISION REDUCTION PACK	S.T.E.	P.C.D.	STAPH. PYOG.	PERSIST	D.P. SUTURE 21ST DAY	NONE		HEALED AT 6 WEEKS - FUNCTION AT 4 MONTHS (CHILD)
18.	TARSAL BONES AND ANKLE JOINT	EXCISION REDUC. STADER SPLINT IN DRESSING SUTURE OF KNEE JOINT. WND. PACKED	S.T.E.	P.C.D.	NONE		D.P. SUTURE 12TH DAY	PROTEUS- NEUS	PERSIST	HEALED AT 5 WEEKS - FUNCTION ONLY MONTHS (CHILD)
19.	FEMUR LOWER THIRD LACERATION OF KNEE JOINT	WHD EXCISION REDUCTION PACK	S.T.E.	P.C.D.	NONE		SEC. SUTURE 6TH WEEK	NONE		HEALED AT 3 WEEKS - FUNCTION AT 4 MONTHS
20.	HUMERUS RIGHT	EXCISION REDUC. STADER SPLINT IN DRESSING SUTURE OF KNEE JOINT. WND. PACKED	S.T.E.	P.C.D.	NONE		SEC. SUTURE 25TH DAY	PROTEUS	PERSIST	HEALED AT 8 WEEKS - FUNCTION - STILL IN PLASTER AT 3 MONTHS
21.	LEFT TIBIA ONLY xx	WHD EXCISION REDUCTION PACK	S.T.E.	P.C.D.	STAPH. PYOG.	PERSIST	D.P. SUTURE 21ST DAY	DISAPPEA AFT. 4 DAY.		HEALED AT 6 WEEKS - FUNCTION AT 8 MONTHS
22.	TARSAL BONES	WOUND EXCISION REDUCTION PACK	S.T.E.	P.C.D.	PROTEUS	PERSIST	D.P. SUTURE 14TH DAY	NONE		HEALED AT 5 WEEKS - FUNCTION AT 5 MONTHS

\* MANY CASES CONTINUED  
xx EXTENSIVE CONTINUATION REQUIRING DOUBLE PIN FIXATION

TABLE A - 5

FRESH TRAUMA

COMPOUND FRACTURES - ARM AND LEG \*

NO.	DIAGNOSIS	PRIMARY SURGERY	BACTERIO-STATIC	TYPE OF DRESSING	INITIAL PATHOGENS	FATE OF SAME	SUBSEQUENT SURGERY	NEW PATHOGENS	FATE OF SAME	CLINICAL RESULTS
23.	BOTH BONES, LT. LEG	WIND EXCISION REDUCTION PACK	S.T.E.	P.C.D.	NONE	PERSIST	D.P. SUTURE 28TH DAY	PROTEUS	PERSIST	HEALED AT 6 WEEKS - FUNCTION AT 7 MONTHS
24.	BOTH BONES, RT. LEG **	WIND EXCISION WIRED	S.T.E.	P.C.D.	STAPH. PYOG.	PERSIST	D.P. SUTURE 14TH DAY	NONE		HEALED AT 4 WEEKS - FUNCTION AT 6 MONTHS
25.	COMP. FRACT. TARSAL BONES ** & ANKLE JOINT	WIND EXCISION. PACK	S.T.E.	P.C.D.	NONE		D.P. SUTURE 24TH DAY	STAPH. PYOG.	PERSIST	HEALED AT 4 WEEKS - FUNCTION AT 3 MONTHS

\* MANY CASES CONTINUED

\*\* EXTENSIVE COMMINUTION REQUIRING DOUBLE PIN FIXATION

TABLE A - 6

FRESH TRAUMA

- B U R N S

NO.	TYPE OF BURN AND AREA	SURGERY	BACTERIO-STATIC	TYPE OF DRESSING	INITIAL PATHOGENS	FATE OF SAME	SECONDARY TREATMENT	NEW PATHOGENS	FATE OF SAME	CLINICAL RESULTS
1.	DEEP BURNS 18%	MECHANICAL CLEANSING & WASHING WITH SOAP & WATER	S.T.E.	C.D.	STAPH. PYOG. STREP. PYOG. A	PERSIST DISAPPEAR	SPLIT SKIN GRAFT 3, 5, & 7 WEEKS			PRIMARY HEALING ALL GRAFTS
2.	" " 10%	"	S.T.E.	C.D.	NONE		SPLIT SKIN GRAFT 17TH DAY	STAPH. PYOG.	PERSIST	PRIMARY HEALING OF GRAFT
3.	" " 10%	"	S.T.E.	C.D.	PROTEUS	PERSIST	SPLIT SKIN GRAFT 20TH DAY	PROTEUS		PARTIAL HEALING INFECTION REGRAFTED SUCCESSFULLY AFTER 3 WEEKS
4.	" " 15%	"	S.T.E.	C.D.	STAPH. PYOG.	PERSIST	" " 20TH DAY	NONE		PRIMARY HEALING OF GRAFT
5.	" " 20%	"	S.T.E.	C.D.	NONE		" " 28TH DAY	NONE		PRIMARY HEALING OF GRAFT
6.	" " 25%	"	S.T.E.	C.D.	STAPH. PYOG.	PERSIST	" " 24TH DAY	NONE		PRIMARY HEALING OF GRAFT
7.	" " 15%	"	S.T.E.	C.D.	STAPH. PYOG.	PERSIST	" " 11TH DAY	NONE		PRIMARY HEALING OF GRAFT
8.	" " 10%	"	S.T.E.	C.D.	STAPH. PYOG.	AT GRAFT ONLY	" " 14TH DAY	NONE		PRIMARY HEALING OF GRAFT
9.	" " 25%	"	S.T.E.	C.D.	STAPH. PYOG.		" " 15TH DAY	NONE		PRIMARY HEALING OF GRAFT
10.	" " 5%	"	S.T.E.	C.D.	STAPH. PYOG.		NONE - HEALED IN 10 DAYS	NONE		PRIMARY HEALING
11.	" " 5%	"	PEN. CR.	C.D.	NONE		NONE - HEALED IN 12 DAYS	STAPH. PYOG.	PERSIST	PRIMARY HEALING
12.	" " 55%	"	S.T.E.	C.D.	STAPH. PYOG. PROTEUS	PERSIST DISAPPEAR	DRESSED FORTHRIGHTLY WITH SPLIT SKIN GRAFTING AT EACH OF 5 RE-DRESSINGS	NONE	PROTEUS REAPPEARED AFTER 3RD DRESS.	GRAFTS UNDER TREATMENT HEALING WELL AT 12 WEEKS
13.	" " 33%	"	S.T.E.	C.D.	STAPH. PYOG.	PERSIST	DRESSED AND GRAFTED AT 19TH, 32ND AND 43RD DAYS	STREP. VIRIDANS	PERSIST	PRIMARY HEALING OF GRAFTS
14.	" " 28%	"	S.T.E.	C.D.	STAPH. PYOG. COLI	PERSIST PERSIST	DRESSED AND GRAFTED AT 17TH, AND 29TH DAYS			
15.	" " 15%	"	S.T.E.	C.D.	NONE		DRESSED AND GRAFTED AT 12TH DAY	STAPH. PYOG.	PERSIST	PRIMARY HEALING OF GRAFTS

FRESH TRAUMA

B U R N S

NO.	TYPE OF BURN AND AREA	SURGERY	BACTERIO- STATIC	TYPE OF DRESSING	INITIAL PATHOGENS	FATE OF SAFE	SUBSEQUENT SURGERY	NEW PA- THOGENS	FATE OF SAFE	CLINICAL RESULTS
16.	DEEP & SUPERFICIAL BURNS 18%	MECHANICAL CLEANSING & WASHING WITH SOAP & WATER	S.T.E.	C.D.	STAPH. PYOG. STREP. PYOG. A	PERSIST DISAPPEAR	DRESSED & GRAFTED 12TH & 22ND DAYS	NONE		HEALING WELL AT 6TH WEEK
17.	CHEMICAL BURNS DEEP & SUP. 7%	"	S.T.E.	C.D.	STAPH. PYOG.	PERSIST	DRESSED & GRAFTED 12TH DAY	NONE		
18.	CHEMICAL BURNS " 28%	"	S.T.E. PEN. INTRA MUSCULARLY	C.D.	STAPH. PYOG.	PERSIST	DRESSED & GRAFTED 13TH, 22ND AND 34TH DAYS	NONE		HEALING DELAYED BY PERSISTENT STAPH. PYOG. FROM PRE-EXISTING ACNE. PENICILLIN USED INTRAMUSCULARLY WITH GOOD EFFECT THOUGH STAPH. PERSIST
19.	DEEP & SUPERFICIAL BURNS 18%	"	S.T.E. PEN. INTRA MUSCULARLY	C.D.	STREP. VIRID. STAPH. PYOG.	PERSIST PERSIST	DRESSED & GRAFTED 16TH, 28TH AND 40TH DAYS	NONE		SAME AS ABOVE - STAPH. PYOG. BECAME PEN. RESISTANT
20.	" " 5%	"	S.T.E.	C.D.	STAPH. PYOG.	PERSIST	DRESSED & GRAFTED 11TH DAY	NONE		HEALED 4TH WEEK
21.	" " 8%	"	S.T.E.	C.D.	STAPH. PYOG.	PERSIST	DRESSED & GRAFTED 9TH DAY	NONE		HEALED 4TH WEEK
22.	SUPERFICIAL BRUSH BURNS 8%	"	S.T.E.	C.D.	STAPH. PYOG.	PERSIST	NONE. DRESSING REMOVED 14TH DAY	NONE		HEALED 14TH DAY
23.	" " 5%	"	S.T.E.	C.D.	STAPH. PYOG.	PERSIST	" " 10TH DAY	NONE		HEALED 10TH DAY
24.	SUPERFICIAL BURNS 20%	"	S.T.E.	C.D.	STAPH. PYOG.	PERSIST	" " 8TH DAY	NONE		HEALED 8TH DAY
25.	" " 20%	"	PEN. CR.	C.D.	STAPH. PYOG.	PERSIST	" " 7TH DAY	STAPH. PYOG.	PERSIST	HEALED 8TH DAY
26.	" " 15%	"	S.T.E.	C.D.	STAPH. PYOG.	PERSIST	" " 10TH DAY	STAPH. PYOG.	PERSIST	HEALED 8TH DAY
27.	" " 25%	"	S.T.E.	C.D.	STAPH. PYOG.	PERSIST	" " 7TH DAY	NONE		HEALED 7TH DAY
28.	" " 10%	"	S.T.E.	C.D.	STAPH. PYOG.	PERSIST	" " 8TH DAY	NONE		HEALED 10TH DAY
29.	" " 25%	"	S.T.E.	C.D.	STAPH. PYOG.	PERSIST	" " 9TH DAY	NONE		HEALED 8TH DAY
30.	" " 28%	"	S.T.E.	C.D.	STAPH. PYOG.	PERSIST	" " 11TH DAY	NONE		HEALED 9TH DAY
31.	" " 20%	"	S.T.E.	C.D.	STAPH. PYOG.	PERSIST	DRESSED 10TH DAY REMOVED 17TH DAY	STAPH. PYOG.	PERSIST	HEALED AT 13 DAYS
32.	" " 25%	"	S.T.E.	C.D.	STAPH. PYOG.	PERSIST	NONE. REMOVED 10TH DAY	NONE		HEALED AT 20 DAYS
33.	" " 18%	"	S.T.E.	C.D.	STAPH. PYOG.	PERSIST	" " 9TH DAY	STAPH. PYOG.	PERSIST	HEALED AT 12 DAYS
34.	" " 15%	"	S.T.E.	C.D.	STAPH. PYOG.	PERSIST	DRESSED 14TH DAY REMOVED 20TH DAY	NONE		HEALED AT 10 DAYS
35.	" " 8%	"	S.T.E.	C.D.	STAPH. PYOG.	PERSIST	NONE. REMOVED 7TH DAY	NONE		HEALED AT 21 DAYS
36.	" " 15%	"	S.T.E.	C.D.	STAPH. PYOG.	PERSIST	NONE. REMOVED 6TH DAY	STAPH. PYOG.	PERSIST	HEALED AT 8 DAYS
37.	" " 20%	"	S.T.E.	C.D.	STAPH. PYOG.	PERSIST	" " 11TH DAY	STAPH. PYOG.	PERSIST	HEALED AT 7 DAYS
38.	" " 12%	"	S.T.E.	C.D.	STAPH. PYOG.	PERSIST	" " 8TH DAY	STAPH. PYOG.	PERSIST	HEALED AT 14 DAYS
39.	" " 14%	"	S.T.E.	C.D.	STAPH. PYOG.	PERSIST	" " 10TH DAY	STAPH. PYOG.	PERSIST	HEALED AT 9 DAYS
40.	" " 14%	"	S.T.E.	C.D.	STAPH. PYOG.	PERSIST	COLI	ONE CULTURE ONLY		HEALED AT 12 DAYS



TABLE A - 6

FRESH TRAUMAB U R N S

NO.	TYPE OF BURN & AREA	SURGERY	BACTERIO- STATIC	TYPE OF DRESSING	INITIAL PATHOGENS	FATE OF SAFE	SUBSEQUENT SURGERY	NEW PA- THOGENS	FATE OF SAFE	CLINICAL RESULTS
41.	SUPERFICIAL BURNS 25%	MECHANICAL CLEANSING & WASHING WITH SOAP & WATER	S.T.E.	C.O.	STAPH.PYOG.	PERSIST	REMOVED AND DRESSED 1 ARM 12TH DAY	NONE		HEALED AT 21 DAYS
42.	" " 30%	"	S.T.E.	C.O.	COLI	PERSIST	REMOVED AND DRESSED 1 LEG 12TH DAY REMOVED 22ND DAY	STAPH.PYOG.	PERSIST	HEALED AT 28 DAYS
43.	" " 8%	"	S.T.E.	C.O.	NONE		NONE. REMOVED 7TH DAY	STAPH.PYOG.	PERSIST	HEALED AT 8 DAYS
44.	" " 35%	"	S.T.E.	C.O.	STREP.PYOG.	DISAPPEAR	DRESSED PARTIALLY 12TH DAY	STAPHY. "	PERSIST	HEALED AT 20 DAYS
45.	" " 12%	"	S.T.E.	C.O.	STAPH.PYOG.	PERSIST	REMOVED 6TH DAY	NONE		HEALED AT 7 DAYS

TABLE A - 7

FRESH TRAUMAMISSILE WOUNDS OF SOFT PARTS

NO.	DIAGNOSIS	INITIAL SURGERY	BACTERIO- STATIC	DRESS- ING	INITIAL PATHOGENS	FATE OF SAFE	SUBSEQUENT SURGERY	NEW PA- THOGENS	FATE OF SAFE	CLINICAL RESULTS
1.	SHRAPNEL WOUNDS BUTTOCKS	WOUND EXCISION PACK	S.T.E.	C.O.	STAPH.PYOG. PROTEUS	PERSIST PERSIST	SEC. SUTURE & RE-DRESSING 21ST DAY DRESSING FORT-NIGHTLY	NONE		DELAY IN HEALING 10 WEEKS
2.	SHRAPNEL WOUNDS BUTTOCKS	" " "	S.T.E.	C.O.	PROTEUS	PERSIST	SEC. SUTURE & RE-DRESSING 21ST DAY DRESSING FORT-NIGHTLY	STAPH.	PERSIST	DELAY IN HEALING 12 WEEKS
3.	SHRAPNEL WOUND BUTTOCKS & LEG	" " "	S.T.E.	C.O.	STAPH.PYOG. PROTEUS	PERSIST PERSIST	SEC. SUTURE & RE-DRESSING 21ST DAY DRESSING FORT-NIGHTLY	NONE		DELAY IN HEALING 10 WEEKS
4.	SHRAPNEL WOUND RT. SHOULDER	" " "	S.T.E.	C.O.	PROTEUS	DISAPPEAR	D.P. SUTURE 14TH DAY	STAPH.PYOG.	PERSIST	SOME DELAY IN HEALING 6 WEEKS
5.	SHRAPNEL WOUND NECK & FACE	" " "	S.T.E.	C.O.	STAPH.PYOG. PROTEUS	PERSIST DISAPPEAR	D.P. SUTURE 7TH DAY	NONE		WOUND HEALED AT END OF 2 WEEKS
6.	GUNSHOT WOUND THIGH THROUGH AND THROUGH	" " "	S.T.E.	C.O.	STAPH.PYOG.	PERSIST	D.P. SUTURE EXIT WOUND 6TH DAY	NONE		HEALED AT 2 WEEKS
7.	REVOLVER WOUND ARM THROUGH AND THROUGH	" " "	S.T.E.	C.O.	NONE		D.P. SUTURE EXIT WOUND 4TH DAY	STAPH.PYOG.	PERSIST	HEALED AT 2 WEEKS
8.	GUNSHOT WOUND CALF THROUGH	" " "	S.T.E.	C.O.	NONE		D.P. SUTURE 6TH DAY	STAPH.PYOG.	PERSIST	HEALED AT 3 WEEKS

TABLE B - 1

## PRE-EXISTING INFECTIONS

## ACUTE SPREADING WITH OR WITHOUT BACTERAEMIA

NO.	DIAGNOSIS	PRIMARY SURGERY	BACTERIO- STATIC	TYPE OF DRESSING	INITIAL PATHOGENS	FATE OF SAFE	SUBSEQUENT SURGERY	NEW PA- THO- GENS	CLINICAL RESULT
1.	INFECTED SARCOMA FOOT LOCAL CELLULITIS	OPEN AMP. SITE OF ELECTION. PACK	S.T.E.	P.C.D.	STREP. PYOG. A STAPH. PYOG.	DISAPPEAR 5 DAYS PERSIST	REVISION & SEC. SUTURE 23RD DAY	NONE	HEALED AT 6 WEEKS. FUNCTION WITH PRO- THESIS AT 4 MONTHS. WELL AT 2 YEARS
2.	GANGRENOUS INFECTION FOOT & LEG JOINT. EXTENSIVE GANGRENE & CELLULITIS CRUSTOSE	OPEN AMP. LOWER 1/3 LEG. 4 HOURS AFTER ADMISSION	S.T.E. SULFA- THIAZOLE INTRAVENOUSLY	P.C.D.	STREP. PYOG. A LOCALLY & BAC- TERIAEMIA	DISAPPEAR BLOOD AT 48 HOURS PERSIST	OPEN RE-AMP. AT SITE OF ELECTION 16TH DAY. REVISION AND SEC. SUTURE AT 28TH DAY	NONE	HEALED AT 6 WEEKS. AWAITING PROTHE- SIS. FIBULAR STUMP REMOVED AT 3 MONTHS WITH PRIMARY HEALING
3.	GANGRENOUS INFECTION OF FOOT FOLLOWING 4 WEEKS' OLD CRUSHING INJURY WITH INTERFERENCE WITH CIRCULATION	OPEN AMP. SITE OF ELECTION	S.T.E. SULFADIA- ZINE ORALLY	P.C.D.	STREP. PYOG. A STAPH. PYOG.	DISAPPEAR AT 48 HOURS PERSIST	REVISION & SEC. SUTURE 23RD DAY	NONE	HEALED AT 6 WEEKS FUNCTION WITH PROTHESIS AT 4 MONTHS
4.	ARTERIOSCLEROTIC GANGRENE WITH INVASIVE INFECTION FOOT & ANKLE	OPEN AMP. SITE OF ELECTION	S.T.E.	P.C.D.	STREP. PYOG. A STAPH. PYOG.	DISAPPEAR PERSIST	REVISION & SEC. SUTURE 23RD DAY	NONE	HEALED AT 6 WEEKS FUNCTION WITH PROTHESIS AT 4 MONTHS
5.	ARTERIOSCLEROTIC GANGRENE WITH EXTENSIVE INVASIVE INFECTION FOOT AND ANKLE	OPEN AMP. SITE OF ELECTION	S.T.E.	P.C.D.	STREP. PYOG. A STAPH. PYOG.	DISAPPEAR PERSIST	REVISION & SEC. SUTURE 24TH DAY	NONE	HEALED AT 6 WEEKS FUNCTION WITH PROTHESIS AT 5 MONTHS
6.	ARTERIOSCLEROTIC GANGRENE WITH INVASIVE INFECTION OF FOOT	OPEN AMP. SUPRA-CONDYLAR FEMUR	S.T.E. SULFADIAZINE ORALLY	P.C.D.	STREP. PYOG. A STAPH. PYOG.	DISAPPEAR PERSIST	REVISION & SEC. SUTURE 19TH DAY	NONE	HEALED AT 4 WEEKS - FUNCTION WITH PROTHESIS AT 3 MONTHS
7.	9 DAY OLD AC. INF. SUPERFICIAL BURN LEG, FEMORAL ADENITIS	WASHING WITH SOAP AND WATER	S.T.E.	P.C.D.	STREP. PYOG. G PROTEUS	PERSIST PERSIST	NONE	NONE	HEALED AT 10 DAYS
8.	5 DAY OLD AC. INF. SUPERFICIAL BURN FACE AND ARM WITH LYMPHAN- GITIS AND ADENITIS	"	S.T.E.	C.D.	STREP. PYOG. A STAPH. PYOG.	DISAPPEAR PERSIST	NONE	NONE	HEALED AT 12 DAYS
9.	6 DAY OLD AC. INF. SUPERFICIAL BURN WRIST AND FOREARM.	"	S.T.E.	C.D.	STREP. PYOG. A STAPH. PYOG.	DISAPPEAR PERSIST	NONE	NONE	HEALED AT 10 DAYS
10.	10 DAY OLD AC. INF. SUPERFICIAL BURN ANKLE AND FOOT. FEMORAL ADENITIS	"	S.T.E.	C.D.	STREP. PYOG. A	DISAPPEAR	NONE	NONE	HEALED AT 10 DAYS
11.	5 DAY OLD AC. INF. SUPERFICIAL BURN FOREARM. LYMPHANGITIS	"	S.T.E.	C.D.	STREP. PYOG. A	DISAPPEAR	NONE	NONE	HEALED AT 10 DAYS
12.	AC. INF. 8 DAY OLD NEGLECTED BURN SCALD AND FACE	"	S.T.E.	C.D.	STAPH. PYOG.	PERSIST	NONE	NONE	HEALED AT 10 DAYS
13.	ACUTE OSTEOMYELITIS, TIBIA	DRAINAGE PACK	S.T.E.	C.D.	STREP. PYOG. A	DISAPPEAR	NONE	NONE	HEALED AT 10 DAYS
14.	SPREAD. CELLULITIS WRIST RIGHT FOREARM AND ELBOW	INGLUTION PACK	S.T.E.	C.D.	STREP. PYOG. A STAPH. PYOG.	DISAPPEAR PERSIST	STAPH. PYOG. PERSIST	HEALED AT 10 DAYS	HEALED AT 10 DAYS
			P.C.D.	STAPH. PYOG. LOCALLY AND BACTERAEMIA	DISAPPEAR FROM BLOOD 3RD DAY PERSIST LOCALLY	AT 3 WKS. DRESSED AT 6 WKS. DRESSED WITH SEC. SKIN GRAFT	PROTEUS PERSIST	HEALED AFTER 4 MONTHS (CHILD)	
			P.C.D.	STREP. PYOG. A	DISAPPEAR	NONE	NONE	NONE	HEALED AT 3 WEEKS

TABLE B - 1

## PRE-EXISTING INFECTIONS

## - ACUTE SPREADING WITH OR WITHOUT BACTERAEMIA

NO.	DIAGNOSIS	PRIMARY SURGERY	BACTERIO- STATIC	TYPE OF DRESSING	INITIAL PATHOGENS	FATE OF SAFE	SUBSEQUENT SURGERY	NEW PA- THOGENS	FATE OF SAFE	CLINICAL RESULT
15.	INF. SMALL ROUND ARM WITH LYMPHANGITIS	NONE	S.T.E.	C.D.	STREP. PYOG. A	DISAPPEAR	NONE. DRESSING REMOVED AT 9 DAYS	NONE		HEALED AT 2 WEEKS
16.	SPREAD. CELLULITIS LEG FROM LACERATION OF SKIN	NONE	S.T.E. SULFATHIA- ZOLE ORALLY	C.D.	STREP. PYOG. A	DISAPPEAR	NONE. DRESSING REMOVED AT 10 DAYS	NONE		HEALED AT 3 WEEKS
17.	SPREADING CELLULITIS FOREHEAD FROM LACERATION	NONE	S.T.E.	C.D.	STREP. PYOG. A	DISAPPEAR	NONE. DRESSING REMOVED AT 9 DAYS	NONE		HEALED AT 10 DAYS
18.	AC. OSTEOCELLITIS TIBIA	DRAINAGE. PACK	S.T.E. PEN. INTRA- MUSC. & IN- TRAVEN.	P.C.D.	STAPH. PYOG. LOCALLY AND BACTERAEMIA	* FROM BLOOD 3RD DAY PERSIST LOCALLY	DRESSED AT 3 WEEKS & AT 6 WKS WITH SEC. SUTURE AND SKIN GRAFT	PROTEUS	PERSIST	HEALED AT 6 MONTHS AFTER SEC. SURGERY (CHILD)
19.	AC. OSTEOCELLITIS HUMERUS	DRAINAGE PACK	S.T.E. SULFATHIA- ZOLE INTRA- VEN. & ORALLY	P.C.D.	STAPH. PYOG. LOCALLY AND BACTERAEMIA	DISAPPEAR FROM BLOOD 4TH DAY PERSIST LOCALLY	DRESSED AT 4 WKS & AT 10 WKS WITH SEC. SUTURE	STREP. PYOG. A	DISAPPEAR	CHRONIC SINUS PERSISTED AT 3 MONTHS (CHILD)
20.	AC. OSTEOCELLITIS RADIUS	DRAINAGE PACK	S.T.E. PEN. INTRA- MUSC.	P.C.D.	STAPH. PYOG. LOCALLY AND BACTERAEMIA	DISAPPEAR FROM BLOOD 3RD DAY PERSIST LOCALLY	DRESSED AT 4 WKS WITH SEC. SUTURE	NONE		HEALED AT 2 MONTHS (CHILD)
21.	AC. INF. SEVERE LACERATION AVULSION INJURY, ARM	MIN. WND EXCISION DEBRIDEMENT	S.T.E.	P.C.D.	STAPH. PYOG.	PERSIST	D.P. GRAFT 21ST DAY	PYOCYANEUS	PERSIST	HEALED AFTER 5 WEEKS
22.	AC. INF. LACERATION HAND WITH ABSCSS AND LYMPHANGITIS	INCISION PACK	B.I.P.P.	C.D.	STAPH. PYOG.	PERSIST	PACK REMOVED AT 14 DAYS C.D.	NONE		HEALED; DRESSING AFTER 21 DAYS
23.	AC. INF. 12 DAYS OLD NEGLECTED BURN ANKLE	NONE	CONTROL BASE	C.D.	STAPH. PYOG.	PERSIST	DRESSING WEEKLY FOR 4 WEEKS	STREP. PYOG. A	DIS- APPEAR	HEALING DELAYED FOR 6 WEEKS
24.	AC. FLEXOR TENOSINOVITIS, MIDDLE FINGER	INCISION PACK	PEN. CR.	P.C.D.	STAPH. PYOG.	PERSIST	DRESSED AT 18 DAYS AND PACK REMOVED	NONE		SLOW HEALING, STILL UNHEALED AFTER 6 WEEKS
25.	AC. INF. HUMAN BITE OF HAND ABSCSS	INCISION PACK	PEN. CR. INTRA- VEN. N.A.B.	P.C.D.	BOR. VINCENTI & FUSIFORMS	* UNTIL HAD GIVEN, THEN GRADUALLY DECREASED	DRESSED EVERY 4 DAYS FINGER AMP. AT 12 DAYS SEC. SUTURE AT 26 DAYS	NONE		HEALING DELAYED FOR 9 WKS
26.	AC. INF. STAB WND BUTTOCK	EXCISION PACK	S.T.E.	C.D.	STAPH. PYOG.	* GRADUALLY	D.P. SUTURE 8TH DAY	NONE		HEALED AT 3 WEEKS
27.	AC. GANG. INF. 5 DAY OLD, AVULSION INJURY OF UPPER ARM INVOLVING 26 CIRCUMF. EXT. SWELL. WHOLE ARM. HAD PRIMARY SUTURE IN COUNTRY	MAX. EXCISION	S.T.E. SUL- FATHIAZOLE INTRA- & ORALLY	P.C.D. SPICA	STREP. PYOG. A & BACTERAEMIA STREP. PYOG. A LOCALLY	DISAPPEARED 48 HOURS DISAPPEARED 3 DAYS	D.P. SPLIT SKIN GRAFT AT 14 DAYS	NONE		HEALED AT 4 WEEKS WORKING AT 9
28.	AC. INF. OF BURN PRE-EXISTING STAPH. PYOGENA	INCISION ABSCESS & FURUNCLES	S.T.E. PEN. INTRA- MUSC.	C.D.	STAPH. PYOG. PYOCYANEUS	PERSIST PERSIST	SEC. SKIN GRAFTING 36 DAYS	STAPH. PYOG. PERSIST BECAME PEN. RESISTANT		HEALING DELAYED (10 WEEKS)
29.	AC. INF. STAB WND FOREARM LYMPHANGITIS	INCISION PACK	S.T.E. SUL- FATHIAZOLE ORALLY	C.D.	STREP. PYOG. A	DISAPPEARED 3 DAYS	D.P. SUTURE AT 6 DAYS	NONE		HEALED AT 2 WEEKS
30.	AC. INF. BLISTER LEFT HEEL	REMOVAL BLISTER TOP	S.T.E.	C.D.	STAPH. PYOG.	DISAPPEARED	NONE. DRESSING REMOV. 8TH DAY			HEALED AT 2 WEEKS
31.	SPREAD. CELLULITIS WND OF ANKLE	NONE	S.T.E.	P.C.D.	STREP. PYOG. A	DISAPPEARED	D.P. SKIN GRAFT AT 12 DAYS	STAPH. PYOG.	PERSIST	HEALED AT 3 WEEKS
32.	SPREAD. CELLULITIS WND OF ARM	NONE	S.T.E. SUL- FATHIAZOLE ORALLY	C.D.	STREP. PYOG. A	DISAPPEARED	DRESSING REMOVED AT 9 DAYS	NONE		HEALED AT 12 DAYS

TABLE B - 2

PRE-EXISTING INFECTIONS												ACUTE INFECTIONS LOCALIZED AND LOCALIZING											
NO.	DIAGNOSIS		PRIMARY SURGERY	BACTERIO-STATIC	TYPE OF DRESSING	INITIAL PATHOGENS	FATE OF SAFE	SECONDARY SURGERY	NEW PA-THOGENS	FATE OF SAME	CLINICAL RESULTS												
1.	AC. SOFT TISSUE ABSCESS OF THE ARM		INCISION PACK	S.T.E.	C.D.	STAPH. PYOG.	PERSIST	D.P. SUTURE 16 DAYS	NONE		HEALED AFTER 5 WEEKS												
2.	AC. INF. CHRONIC LEG ULCER (A) ABSCESS IN UPPER THIGH (B) ABSCESS IN LOWER LEG (A) & (B) METASTATIC		A) INCISION PACK B) INCISION PACK	A) S.T.E. B) PEN. CR.	P.C.D. P.C.D.	A) STREP. HAEMO. NOT A, B, OR C B) STREP. HAEMO. NOT A, B, OR C	DIS-APPEARED	THIGH D.P. SUTURE AT 14 DAYS D.P. GRAFT AND SUTURE AT 14 DAYS. LEG	NONE	PERSIST	ALL AREAS HEALED AT 5 WKS												
3.	AC. PALMAR ABSCESS		INCISION PACK	B.I.P.P.	C.D.	STREP. PYOG. A	DISAPPEARED	DRESSING ON 10TH DAY	NONE		HEALED AT 17 DAYS												
4.	CARBUNCLE - BACK		EXCISION PACK	PEN. CR.	C.D.	STAPH. PYOG.	PERSIST	DRESSED WEEKLY SEC. GRAFTING AT 18 DAYS	STAPH. PYOG.	PERSIST	HEALED AT 4 WEEKS												
5.	CARBUNCLE - BUTTOCK		EXCISION PACK	PEN. CR.	C.D.	STAPH. PYOG.	PERSIST	DRESSED EVERY 5 DAYS	NONE		HEALED AT 4 WEEKS												
6.	CARBUNCLE - NECK		EXCISION PACK	PEN. CR.	C.D.	STAPH. PYOG.	PERSIST	DRESSED & SEC. SUTURE 2 WKS	NONE		HEALED AT 4 WEEKS												
7.	SUBCUTANEOUS PALMAR ABSCESS		INCISION PACK	PEN. CR.	C.D.	STAPH. PYOG.	PERSIST	DRESSED AT 1 WEEK " AT 12 DAYS	NONE		HEALED AT 4 WEEKS												
8.	AC. INF. LACERATION HAND ABSCESS		INCISION PACK	PEN. CR.	C.D.	STAPH. PYOG.	PERSIST	DRESSED AT 2 WEEKS " AT 3 WKS	NONE		HEALED AT 4 WEEKS												
9.	CARBUNCLE NECK		EXCISION PACK	S.T.E.	P.C.D.	STREP. PYOG. A	DISAPPEARED	DRESSED EVERY 5 DAYS	NONE		HEALED AT 3 WEEKS												
10.	CARBUNCLE NECK		EXCISION PACK	S.T.E.	C.D.	STAPH. PYOG.	PERSIST	EXCISION & SUTURE AT 2 WKS	NONE		HEALED AT 4 WEEKS												
11.	INF. LACERATION HAND, ABSCESS		EXCISION PACK	S.T.E.	C.D.	STAPH. PYOG.	PERSIST	DRESSED AT 14 DAYS REMOVED AT 3 WEEKS	NONE		HEALED AT 4 WEEKS												
12.	AC. THENAR ABSCESS		EXCISION PACK	S.T.E.	C.D.	STAPH. PYOG.	PERSIST	DRESSED AT 14 DAYS REMOVED AT 4 WEEKS	NONE		HEALED AT 4 WEEKS												
13.	CARBUNCLE NECK		EXCISION PACK	S.T.E.	C.D.	STAPH. PYOG.	PERSIST	DRESSED AT 10 DAYS	NONE		HEALED AT 4 WEEKS												
14.	CARBUNCLE BUTTOCK		EXCISION PACK	S.T.E.	C.D.	STAPH. PYOG.	PERSIST	DRESSED WEEKLY NONE	NONE		HEALED AT 3 WEEKS												
15.	CARBUNCLE NECK		EXCISION PACK	S.T.E.	C.D.	STAPH. PYOG.	PERSIST	DRESSED WEEKLY SEC. SUTURE 2 WEEKS	NONE		HEALED AT 3 WEEKS												
16.	AC. THENAR ABSCESS		EXCISION PACK	PEN. CR.	C.D.	STAPH. PYOG.	PERSIST	DRESSED, SUTURE AT 2 WKS	NONE		HEALED AT 4 WEEKS												
17.	AC. THENAR ABSCESS		EXCISION PACK	S.T.E.	C.D.	STAPH. PYOG.	PERSIST	DRESSED, SUTURE AT 2 WKS	NONE		HEALED AT 4 WEEKS												
18.	CARBUNCLE NECK		EXCISION PACK	S.T.E.	C.D.	STAPH. PYOG.	PERSIST	DRESSED EVERY 4 DAYS	NONE		HEALED AT 4 WEEKS												
19.	CARBUNCLE NECK, NOT BROKEN DOWN		EXCISION PACK	S.T.E.	C.D.	STAPH. PYOG.	PERSIST	NONE	NONE		HEALED AT 5 WEEKS												
20.	SEVERE INF. FACE ANGULAR VEIN THROMBOSIS		NONE	NONE	NONE	NONE	NONE	NONE	NONE		HEALED AT 26 DAYS												
21.	CARBUNCLE BUTTOCK, NOT BROKEN DOWN		EXCISION PACK	PEN. INTRA-MUSC.	C.D.	STAPH. PYOG.	PERSIST	NONE	NONE		HEALED AT 10 DAYS												
22.	CARBUNCLE BUTTOCK, EXCISION PACK		EXCISION PACK	PEN. CR.	C.D.	STAPH. PYOG.	PERSIST	NONE	NONE		HEALED AT 14 DAYS												
23.								PROTEUS	PERSIST	" AT 10 DAYS	HEALED AT 21 DAYS												

TABLE B - 2 PRE-EXISTING INFECTIONS - ACUTE INFECTIONS LOCALIZED AND LOCALIZING

NO.	DIAGNOSIS	PRIMARY SURGERY	BACTERIO-STATIC	TYPE OF DRESSING	INITIAL PATHOGENS	FATE OF SAME	SECONDARY SURGERY	NEW PATHOGENS	FATE OF SAME	CLINICAL RESULTS
24.	LARGE SUBCUTANEOUS ABSCESS HAND	INCISION PACK	S.T.E.	P.C.D.	STAPH., PYOS., PYOCYANUS	PERSIST PERSIST	DRESSED AT 14 DAYS REMOVED AT 3 WEEKS	NONE		HEALED AT 4 WEEKS
25.	THUMB ABSCESS	INCISION PACK	S.T.E.	P.C.D.	STAPH., PYOS.	PERSIST	DRESSED & D.P. SUTURE AT 16 DAYS	NONE		HEALED AT 5 WEEKS
26.	PALMAR ABSCESS	INCISION PACK	PEN. CR.	P.C.D.	STAPH., PYOS.	PERSIST	DRESSED & D.P. SUTURE AT 17 DAYS	NONE		HEALED AT 6 WEEKS
27.	SUPP. TENDONITIS MID-FINGER CELLULITIS, ABSCESS LUMBRICAL SPACE AL	MULTIPLE INCISION PACK	S.T.E.	C.D.	STAPH., PYOS., STREP., PYOS. A	PERSIST DISAPPEAR	DRESSED & D.P. SUTURE AT 15 DAYS	NONE		HEALED AT 7 WEEKS
28.	PALMAR ABSCESS	INCISION PACK	S.T.E.	C.D.	STAPH., PYOS.	PERSIST	DRESSED & D.P. SUTURE AT 2 WKS	NONE		HEALED AT 5 WEEKS
29.	LUMBRICAL SPACE ABSCESS	INCISION PACK	S.T.E.	C.D.	STREP., PYOS. A	DISAPPEAR	DRESSED WEEKLY	STAPH., PYOS.	PERSIST	HEALED AT 4 WEEKS

TABLE B - 3 PRE-EXISTING INFECTIONS - CHRONIC INFECTIONS - PYOGENIC

NO.	DIAGNOSIS	PRIMARY SURGERY	BACTERIO-STATIC	TYPE OF DRESSING	INITIAL PATHOGENS	FATE OF SAME	SECONDARY SURGERY	NEW PATHOGENS	FATE OF SAME	CLINICAL RESULTS
1.	CHR. OSTEOMYELITIS HUMERUS	SEQUESTRECTOMY & SAUCERIZATION PACK	S.T.E.	C.D.	STAPH., PYOS.	PERSIST	NONE. DRESSED FORT-NIGHTLY	STREP., PYOS. A	(IN ONE CULTURE ONLY)	SMALL PERSISTENT SINUS AFTER 4 MONTHS REMOVED HEALED 6 MONTHS
2.	CHR. OSTEOMYELITIS HUMERUS RESIDUAL SEQUESTRUM	SEQUESTRECTOMY & SAUCERIZATION PACK	S.T.E.	C.D.	NONE		DRESSED FORT-NIGHTLY	STAPH., PYOS.	PERSIST	PERSISTENT SINUS AFTER 4 MONTHS REQUIRES SURGERY
3.	CHR. OSTEOMYELITIS TROCHANTER	SEQUESTRECTOMY SAUCERIZATION PACK	S.T.E.	C.D.	STAPH., PYOS.	PERSIST	DRESSED FORT-NIGHTLY	NONE		PERSISTENT SINUS & SEQUESTRUM AFTER 4 MONTHS
4.	CHR. OSTEOMYELITIS, TIBIA BRODIE ABSCESS	SAUCERIZATION PACK	S.T.E.	P.C.D.	STAPH., PYOS.	PERSIST	DRESSED SEG. SPLIT SKIN GRAFT AT 21ST DAY	NONE		HEALED AFTER 6 WEEKS
5.	CHR. OSTEOMYELITIS, TIBIA BRODIE ABSCESS	SAUCERIZATION PACK	S.D.E.	P.C.D.	STAPH., PYOS.	PERSIST	DRESSINGS AT 3 WEEKS INTERVALS	NONE		HEALED COMPLETELY AT 9 WEEKS
6.	CHR. OSTEOMYELITIS, TIBIA SEQUESTRUM	SAUCERIZATION PACK	S.D.E.	P.C.D.	STAPH., PYOS., STREP., PYOS. A	PERSIST DISAP. AT 3 DAYS	DRESSINGS AT 3 WEEK INTERVALS	PYOCYANUS	PERSIST	HEALED AT 8 WEEKS (CHILD)
7.	CHR. OSTEOMYELITIS, TIBIA SEQUESTRUM	SAUCERIZATION PACK	PROFLAVINE E.	P.C.D.	STAPH., PYOS.	PERSIST	DRESSINGS AT 3 WEEKS INTERVALS	NONE		HEALED AT 2 MONTHS
8.	A) CHR. OSTEOMYELITIS PELVIS ABSCESS THIGH B) CHR. OSTEOMYELITIS & SEQUESTRUM	INCISION SEQUESTRECTOMY PACK	PEN. CR. PEN. CR.	C.D. C.D.	STAPH., PYOS. STAPH., PYOS.	PERSIST PERSIST	DRESSED WEEKLY DRESSED FORTNIGHTLY	NONE NONE		HEALED AFTER 5 WEEKS PERSISTENT SINUS FURTHER SURGERY, HEALED 10 WKS
9.	CHR. OSTEOMY. TIBIA BRODIE ABSCESS DEEP	SAUCERIZATION PACK	S.T.E.	P.C.D.	STAPH., PYOS.	PERSIST	DRESSED MUSCLE GRAFT 2 WKS SPLIT SKIN GRAFT 4 WKS	NONE		HEALED AFTER 8 WEEKS

PRE-EXISTING INFECTIONS

CHRONIC INFECTIONS - PYOGENIC

NO.	DIAGNOSIS	PRIMARY SURGERY	BACTERIO- STATIC	TYPE OF DRESSING	INITIAL PATHOGENS	FATE OF SAFE	SECONDARY SURGERY	NEW PA- THOGENS	FATE OF SAFE	CLINICAL RESULTS
10.	CHR. OSTEOMY. TIBIA BRODIE ABSCESS	SAUCERIZATION PACK	PEN.CR.	P.C.D.	STAPH.PYOG.	PERSIST	DRESSED FORTNIGHTLY SEC. SKIN GRAFT 4 WKS	NONE		HEALED AT 12 WEEKS
11.	CHR. OSTEOMY. TIBIA BRODIE ABSCESS	SAUCERIZATION PACK	PEN.CR.	P.C.D.	STAPH.PYOG.	PERSIST	DRESSED FORTNIGHTLY SEC.SKIN GRAFT 4 WKS	NONE		HEALED AT 12 WEEKS
12.	CHR. OSTEOMY. HUMERUS WITH SEQUESTRUM	SEQUESTRECTOMY PACK	PEN.CR.	C.D.	STAPH.PYOG.		DRESSED WEEKLY	NONE		HEALED AT 4 WEEKS
13.	CHR. OSTEOMY. TIBIA	SAUCERIZATION PACK	PEN.CR. PEN.SOL.N PEN.INTRA- MUSC.	P.C.D.	STAPH.PYOG.	PEN.FAST ORGANISMS	DRESSED SKIN GRAFT AT 1 MONTH	NONE		HEALED AT 2 MONTHS
14.	CHR. OSTEOMY. RADIUS	SAUCERIZATION PACK	PEN.CR. PEN.INTRA- MUSC.	P.C.D.	STAPH.PYOG.	PERSIST	DRESSED 1 MONTH SUTURE SEC. SUTURE	NONE		HEALED AT 8 WEEKS
15.	CHR. OSTEOMY. FEMUR SEQUESTRUM	SEQUESTRECTOMY SAUCERIZATION PACK	PEN.CR. PEN.INTRA- MUSC.	P.C.D.	STAPH.PYOG.	PERSIST	DRESSED 3 WEEKS SEC.SUTURE	NONE		HEALED AT 9 WEEKS
16.	CHR. OSTEOMY. FEMUR	SAUCERIZATION PACK	S.T.E.PEN. INTRAVEN.	P.C.D.	STAPH.PYOG.	PERSIST	DRESSED 3 WKS SEC. SUTURE	NONE		HEALED AT 8 WEEKS
17.	CHR. OSTEOMY. RADIUS	SAUCERIZATION PACK	S.T.E.	P.C.D.	STAPH.PYOG.	PERSIST	DRESSED 3 WKS SEC. SUTURE	NONE		HEALED AT 8 WEEKS
18.	CHR.LEG ULCER	NONE	S.T.E.	P.C.D.	STAPH.PYOG.	PERSIST	DRESSED 3 WKS SEC. SUTURE	NONE		HEALED AT 8 WEEKS
19.	CHR. LEG ULCER	EXCISION PACK	S.T.E.	P.C.D.	STAPH.PYOG.	PERSIST	DRESSED 3 WKS SEC. SUTURE	NONE		HEALED AT 8 WEEKS
20.	CHR. LEG ULCER	EXCISION PACK	S.T.E.	P.C.D.	STAPH.PYOG.	PERSIST	DRESSED 3 WKS SEC. SUTURE	NONE		HEALED AT 8 WEEKS
21.	CHR. LEG ULCER	EXCISION PACK	S.T.E.	P.C.D.	STAPH.PYOG.	PERSIST	DRESSED 3 WKS SEC. SUTURE	NONE		HEALED AT 8 WEEKS
22.	CHR. LEG ULCERS, TROPHIC	NONE	CONTROL THEN S.D.E.	P.C.D.	STAPH.PYOG.	PERSIST	D.P. SKIN GRAFT 18TH DAY	NONE		HEALED AT 6 WKS (CHILD)
23.	CHR. LEG ULCER	NONE	PEN.CR.	C.D.	STAPH.PYOG.	PERSIST	D.P. SKIN GRAFT 10 DAYS GRAFT TOTAL LOSS RE-DRESS S.D.E. 1 WK RE-GRAFT WITH S.D.E.	STAPH.PYOG.	PERSIST	HEALED AFTER 4 WKS
24.	CHR. LEG ULCER	NONE	PEN.CR.	P.C.D.	STAPH.PYOG.	PERSIST	DRESSED WEEKLY	STAPH.PYOG.	PERSIST	100% TAKE OF SECOND GRAFT 1ST GRAFT DISAP.WITH S.D.E.BEFORE 2ND 2 WKS
25.	CHR. LEG ULCER	NONE	S.T.E.	C.D.	STAPH.PYOG.	PERSIST	DRESSED WEEKLY	NONE		HEALED AFTER 5 WKS
26.	CHR. LEG ULCER	NONE	S.T.E.	P.C.D.	STAPH.PYOG.	PERSIST	DRESSED WEEKLY	NONE		HEALED AT 4 WKS
27.	CHR. LEG ULCER	NONE	S.T.E.	C.D.	STAPH.PYOG.	PERSIST	D.P. SKIN GRAFT AFTER 2 WKS REMOVED 4 WKS	NONE		HEALED AT 4 WKS
28.	CHR. OSTEITIS TIBIA TRAUMATIC	SAUCERIZATION PACK	PEN.CR.	P.C.D.	STAPH.PYOG.	PERSIST	D.P. SKIN GRAFT AT 2 WKS REMOVED 4 WKS	NONE		HEALED AT 5 WKS
							D.P. SKIN GRAFT AT 2 WKS REMOVED DRESSED FORTNIGHTLY	NONE		HEALED AT 6 WKS
								NONE		HEALED AT 5 WKS
										GRAFTED SITE HEALED AFTER 6 WKS

2. *Acute localized and localizing infections (one control). (29 cases including carbuncles; and abscesses of various regions.)*\*

Treated surgically as the previous group and with equally successful results. It may be noted that in this group three cases of acute staphylococcal infection were successfully treated by systemic penicillin, surgery not being indicated.

3. *Chronic pyogenic infections (two controls). (29 cases including chronic osteomyelitis and chronic leg ulcers.)*

In all cases surgery was found to be of greater usefulness in achieving results than bacteriostatics of any type. Topical sulfathiazole was found to be useful following each surgical procedure, topical penicillin,<sup>7</sup> by contrast, was less satisfactory, and this substance was more usefully administered systemically. In a few pyogenic empyemata, not shown in the tables, topical penicillin in solution has been found to be very satisfactory bacteriologically but, as elsewhere, has led to further surgical problems, and drainage is definitely indicated.

N. B. Secondary suture and split-skin grafting were employed as in all other groups.

The following points summarize the authors' convictions. They form the basis for the subsequent discussion:

1. The nature, age and extent of any injury or infection profoundly modify the value of any antibiotic substance.

2. Adequate surgery is more essential in the treatment of trauma than are chemotherapeutic substances.

3. The mere presence of bacteria in a wound is by no means synonymous with infection.

4. Bacteria tend to persist in a healing wound up to the time of complete and final epithelization without clinical signs of infection.

5. Pyogenic streptococci regularly disappear from wounds and preëxisting infections treated with sulfonamides or penicillin. Most other wound pathogens, notably *Staphylococcus pyogenes*, *B. proteus vulgaris*, *Ps. pyocyanea* and *Cl. welchii* persist in the presence of chemotherapy without necessarily producing clinical infection.

6. Bacteria in wounds were a far greater hazard in presulfonamide days than at present, despite our inability to sterilize a wound completely.

7. Penicillin topically applied has not proved as effective an agent as sulfathiazole, probably because of its rapid disappearance, which makes frequent exposure of the wound necessary. Its routine systemic use in a large ward with normal personnel is much more burdensome than the more convenient sulfonamides.

8. It seems inescapable that bacteriostatics help to restrain the contaminated wound from becoming an infected wound. This they must do by prolonging the important "lag-period," restraining during this time free bacterial multiplication, and allowing elaboration of the natural barrier to microbic invasion.

9. All this is facilitated by immobilization and occlusive compression dressings, infrequently changed.

10. Hypersensitivity reaction from topically applied sulfonamides is a highly controversial issue. We, however, have seen such little evidence of it with infrequent dressings that we consider the risk entirely unimportant.

11. We have no convincing evidence that such bacteriostatics as we have used significantly influence *Ps. pyocyanea* or *B. proteus vulgaris* in a wound. These remain one of our outstanding problems.

12. Either to condemn bacteriostatics unreservedly or to endorse them as "miracle drugs" is to evince completely uncritical judgment. The truth, as usual, lies somewhere between. In our opinion, as far as trauma is concerned, the most efficient of them is, at best, only the junior partner of adequate surgery.

13. In chronic surgical infections, surgery is paramount. In acute localized infections, surgery and chemotherapy are interdependent. In acute spreading infections, chemotherapy is the immediate necessity.

The conclusions previously stated will now be discussed in some detail.

1—*The nature, age and extent of any injury profoundly modify the use of any antibiotic substance.*

These studies confirm our previous findings in showing a great difference between the effectiveness of such antibiotic substances as sulfonamides, employed prophylactically in a case of fresh trauma, and their therapeutic value in an extensive preëxisting infection. It is quite useless to discuss the value of the topical use of any antibiotic substance in the presence of a severe spreading acute infection, with or without bacteriemia. In the latter case it is obvious that only systemic attack, by whatever route possible and with whatever bacteriostatic agent is most specific, is the method of achieving clinical success. Case 2, Table B-1, previously mentioned, is an excellent illustration of this. By contrast, a superficial infection with *Streptococcus pyogenes* is apparently easily controllable with topical application of at least any of the sulfonamides (or penicillin). Recent injuries coming under observation during the "lag-period" lend themselves well to topical therapy. In older lesions, particularly those with extensive tissue devitalization, the influence of bacteriostatics is not so marked. Many reports in the literature have failed to give these facts due consideration.

2—*Adequate surgery is more essential in the treatment of trauma than are chemotherapeutic substances.*

This statement is fundamental, and must also include an appreciation of the value of the infrequent change of compressive immobilizing dressings. It has been demonstrated to us beyond doubt that clinical failure in any of our cases can be traced to inadequate surgery of some sort, including inadequate drainage. An example of this is shown by the fact that the only two existing infected cases which failed to show proper response were proved to have inadequate incision for drainage. It may be pointed out that tension from



tight suturing is a prime factor in promoting local infection, such as stitch abscesses. It seems to us superfluous to have to restate this matter, though Churchill,<sup>2</sup> in his report from North Africa and Italy, found it expedient to do so. Bacteriostatics have a useful supporting rôle, insofar as they extend the "lag-period" and make many surgical procedures far safer.

3—*The mere presence of bacteria in a wound is by no means synonymous with infection.*

It is certain that no military or civilian accident ever presents a sterile wound. All of them are contaminated. The majority of them remain contaminated up to the time of healing, yet, under appropriate treatment, few ever give clinical signs of infection. Infection has an incubation period and must, therefore, be considered related to bacterial multiplication. Bacteriostatics, especially if applied early, should obviously minimize this risk. Again, infection is related to the spread of bacteria from the point of entry. This spread, determined in a considerable measure by the species of microbe, will be along existing channels—lymphatics, fascial planes, tissue spaces—but always in the tissue fluids. Any massaging influence will facilitate this spread, and immobilization with compression dressings will minimize it. The two factors of bacteriostasis and immobilization are intimately concerned with preventing a contaminated wound from becoming an infected one (see tables).

4—*Bacteria often persist in the healing wound up to the time of complete and final epithelization without clinical signs of infection.*

Explanation of this is found in the main in comments in the previous paragraph. It is not, in our opinion, the exception but rather the rule, as our tables clearly indicate.

5—*Pyogenic streptococci regularly disappear from wounds and preëxisting infections treated with sulfonamides. Most other wound pathogens, notably Staphylococcus pyogenes, B. proteus vulgaris, Ps. pyocyanea, Cl. welchii, persist in the presence of chemotherapy without necessarily producing clinical infection.*

Success in the elimination of pyogenic streptococci in our cases, with topical application alone, is, we feel, the most significant factor in the prevention of infection in fresh trauma. Moreover, the regularly successful elimination of many extensive and even invasive local streptococcal infections by topical sulfonamides alone has conclusively proved the value of the topical chemotherapy for these organisms. Much can be said in elaboration of this statement and will be dealt with in a later report. Excellent examples of the clearing of infection from wounds can be found in the tables as, for example, the infected burns. It is probable that elimination of the streptococcus, which was the great infection menace of World War I, has also decreased the opportunities for other pathogens. It seems inescapable that some restraint in their growth occurs, for in only a very few of our cases was there prolonged delay in wound healing. In most cases, healing was entirely uninterrupted in spite of persistence of bacteria. *Staphylococcus pyogenes*, and *Cl. welchii*

respond to chemotherapy under appropriately favorable conditions. It is generally maintained, however, that *B. proteus vulgaris* and *Ps. pyocyanea* are not influenced by present-day bacteriostatics.\* It is probable, therefore, that such success as we have had in this admittedly small series, is due to the surgical and dressing technic and not to the bacteriostatic.

6—*Bacteria in wounds were a far greater hazard in presulfonamide days than at present despite our inability to sterilize a wound completely.*

This statement has been covered in the foregoing paragraph and requires no further elucidation.

7—*Penicillin topically applied has not proved as effective an agent as sulfathiazole, probably because of its rapid disappearance which makes frequent exposure of the wound necessary. Its systemic use in a large ward, with normal personnel, is much more burdensome than the more convenient sulfonamides.*

We have had over a year's experience with topical application of this substance, mainly in various cream bases. It is our frank opinion that, in the main, their topical use has been disappointing. We have found it roughly equivalent to sulfathiazole in its effect on streptococcus in wounds, but equally ineffective where the staphylococcus was concerned. Penicillin is either destroyed or eliminated from the local application, even when large amounts are used, in a matter of hours rather than days. The cause of this elimination is rapid absorption on the one hand, aided, on occasion, by destruction by penicillinase-producing organisms. The natural deduction from this is that, practically speaking, its employment is restricted only to very superficial and localized lesions in which there is no danger whatever of contamination by coliform organisms. Finally, this disability, which is not true of the sulfonamides, would make penicillin impractical as a general bacteriostatic agent in the cream form.

8—*It seems inescapable that bacteriostatics help to restrain the contaminated wound from becoming an infected wound. This they must do by prolonging the important "lag-period," restraining during this time free bacterial multiplication and allowing elaboration of the natural barrier to microbic invasion.*

This statement, again, requires little further elaboration.

9—*All this is facilitated by immobilization wherever possible and occlusion by compression dressings.*

The importance of establishing the practice of immobilization with large, bulky, and other occlusive compression dressings, cannot be overemphasized. These dressings require no change until some specific surgical intervention is planned, or until healing has occurred. Their time of change has depended upon the above factors only, whether that time be a matter of days or weeks, as in compound fractures. We would reiterate the point already made, in previous reports, that frequent change of dressings not only allows for con-

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\* This was written prior to our experience with Streptomycin. Data in this field being collected now for future publication.

tamination by pathogens, but always carries with it the risk of damage to healing tissues, with bleeding and further risk of infection. We believe that the practice described is already well established.

#### 10—*Hypersensitivity to sulfonamides.*

This highly controversial issue has been constantly under our scrutiny since the outset of this work. The fact that in only a single instance in our series of some 250 cases has there been a generalized rash, and in only two cases a local irritation, has led us to consider this matter as unimportant when the practice of infrequent dressing is carried out. It is perhaps noteworthy that two of these three cases lost their hypersensitivity within a year. Investigations prior to this project by one of the authors (F. D. A.<sup>8</sup>) showed no consistently important blood levels, even when large quantities of sulfonamides were used topically. The systemic use of the drug has been confined by us to only those very few cases where widespread extensive infection, with or without bacteriemia had preëxisted. We are not, here, concerned with hypersensitivity as a result of systemic therapy. Confining our comments, therefore, to topical therapy, we can find no objection whatever on this score, provided the practice of infrequent dressings is followed. It has been known to us, as well as to others,<sup>1, 4, 5</sup> that the abuse of therapy by too frequent applications may lead to a considerable percentage of hypersensitivity.

11—*We have no convincing evidence that such bacteriostatics as we have used significantly influence Ps. pyocyanea or B. proteus vulgaris in a wound.*

These remain among our outstanding problems.

12—*Either to condemn bacteriostatics unreservedly or to endorse them as "miracle drugs" is to evince completely uncritical judgment. The truth, as usual, lies somewhere between. In our opinion, as far as trauma is concerned, the most efficient of them is, at best, only the junior partner of adequate surgery.*

This statement requires no elaboration.

13—*In chronic surgical infections surgery is paramount. In acute localized infections, surgery and chemotherapy are interdependent. In acute spreading infections chemotherapy is the immediate necessity.*

This statement requires no elaboration.

The mechanisms underlying wound infection and wound healing clearly involve many factors, among them the state of nutrition of the patient and the general physiologic condition of the tissues. Evaluation of the rôle of chemotherapy, and, indeed, of surgery, must take into account these other factors. We have tended of late to look upon traumatic wounds as being, in a fashion, contaminated tissue cultures, with the rest of the body serving essentially to nourish and incubate both host cells and bacteria. The object of all the influences brought to bear in the name of therapy is to minimize the possible adverse effects of bacterial multiplication without depressing, indeed, if possible with stimulating, the reparative process of the host's tissue

cells. It is the interplay of the factors involved in this process which we propose to examine at greater length in a subsequent publication.

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# PAIN IN MEN WOUNDED IN BATTLE

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THERE IS A COMMON BELIEF that wounds are inevitably associated with pain, and, further, that the more extensive the wound the worse the pain. Observation of freshly wounded men in the Combat Zone showed this generalization to be misleading. If one may speak of such a subjective experience as pain in exact terms, the generalization can be said to hold in only about one-quarter of severely wounded men; it fails in the remaining three-quarters. There are practical reasons for examining this problem, for a clear appreciation of its nature will lead to improved treatment of the distress of the wounded.

The widespread tendency to serious error in the employment of one of the most useful drugs in medicine, morphine, also suggested that the treatment of pain in wounded men needed to be reviewed. An opportunity to do this was made possible during the prolonged action on the Venafrò and Cassino Fronts and later at the Anzio Beachhead and in France.

### MATERIAL

The factual material which serves as the basis for the observations made here is largely presented in Table I. Consecutive cases were observed, insofar as this was possible. There was no selection of patients other than (a) they had one of five kinds of severe wounds chosen as representative; extensive peripheral soft-tissue injury, compound fracture of a long bone, a penetrated head, a penetrated chest, or a penetrated abdomen; (b) they were clear mentally; and (c) they were not in shock at the time of questioning. (If shock was present on arrival, as in a few cases, questioning was delayed until the shock had been relieved.) Men wounded in battle usually have multiple wounds. The categories listed refer to the chief wound.

### INCIDENCE OF PAIN

Three factors are of major importance in the suffering of badly wounded men: pain; mental distress; and thirst. Therapy has been almost entirely directed to pain, and this usually limited to the administration of morphine in large dosage. In a consideration of the pain of seriously wounded men it is advisable to distinguish between those in good general condition and those in shock. Pain and mental distress are encountered in the former group; but in well-developed traumatic shock such suffering as can be detected is commonly not from wound pain or anxiety, but is chiefly from thirst. This will be discussed briefly a little later.

To get at the incidence of pain in the several groups of patients, questions asked shortly after entry in a Forward Hospital were phrased in this way: "As you lie there are you having any pain?" (Care was taken to be certain

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that the patient understood the question.) If the answer was "No," that part of the questioning was dropped. If the answer was "Yes," further inquiry was made: "Is it slight pain, or moderate pain, or bad pain?" There was usually little hesitation about differentiating here. The patients who said they were having pain of any degree were asked further if the pain was great enough that they wanted something to relieve it. (It became apparent early that morphine was an unfortunate word to use in this questioning, and it was avoided, since some were alarmed by the implication that they were "bad enough" to need this agent.) The findings are recorded in Table I.

TABLE I

215 PATIENTS WITH MAJOR WOUNDS

(Standard Errors of the Mean are Shown)

Type of Wound	Compound Fractures of Long Bones	Extensive Soft-tissue Wounds	Penetrating Wounds of Thorax	Penetrating Wounds of Abdomen	Penetrating Wounds of Cerebrum
Number of pts.	50	50	50	50	15
Pt's age (yrs.)	24.8 ± 0.9	24.5 ± 1.1	24.5 ± 0.8	22.7 ± 0.6	25.1 ± 1.4
Time since wound- ing (hrs.)	12.5 ± 1.3	11.3 ± 1.4	9.8 ± 1.0	7.2 ± 0.7	7.9 ± 1.4
Avg. total dose of morphine (mg.)	1 pt.: none* 49 pts. avgd. 27.0 ± 1.5	11 pts.: none* 39 pts. avgd. 27.0 ± 2.7	11 pts.: none* 39 pts. avgd. 25.0 ± 1.8	5 pts.: none* 45 pts. avgd. 29.0 ± 2.2	8 pts.: none* 7 pts. avgd. 19.8 ± 4.2
Avg. latest dose of morphine (mg.) (spread as above)	22.6	19.5	21.2	25.0	19.8
Time since latest morphine (hrs.)	7.0 ± 0.8	7.2 ± 0.6	6.5 ± 0.6	4.8 ± 0.7	6.2 ± 1.5
Pain (degree).	19 none	19 none	15 none	7 none	9 none
(Number of pts. in each group)	12 slight 7 moderate 12 bad	15 slight 8 moderate 8 bad	18 slight 11 moderate 6 bad	5 slight 14 moderate 24 bad	5 slight 0 moderate 1 bad
Further pain relief therapy wanted (pts.)	11 yes 39 no	9 yes 41 no	10 yes 40 no	27 yes 23 no	1 yes 14 no
Remarks on pts. with "bad pain" (morphine in mg.)	12 pts. avg. lat- est dose mor- phine 24.8, 5.7 hrs. ago; avg. total dose 33.6	7 pts. (1 no mor- phine*) avg. lat- est dose mor- phine 22.8, 9 hrs. ago; avg. total dose 33.0	5 pts. (1 no mor- phine*) avg. lat- est dose mor- phine 19.0, 6 hrs. ago; avg. total dose 23.9	21 pts. (3 no morphine*) avg. latest dose mor- phine 26.0, 5 hrs. ago; avg. total dose 29.4	Only 1 pt. re- ported bad pain. he had mor- phine 30.0, 14 hrs. ago (com- pare with avg.)
Remarks on pts. where no further pain relief therapy wanted (morphine in mg.)	Avg. total mor- phine in 38 pts. (1 no morphine*) 28.1; latest dose 7.4 hrs. ago (avg.)	Avg. total mor- phine in 30 pts. (11 no morphine*) 27.5; latest dose 6.5 hrs. ago (avg.)	Avg. total mor- phine in 30 pts. (10 no morphine*) 26.1; latest dose 6.4 hrs. ago (avg.)	Avg. total mor- phine in 21 pts. (2 no morphine*) 30.1; latest dose 5.1 hrs. ago (avg.)	8 pts. had no morphine here. Others received only 1 dose; (for size and time see above)

\* Not included in the average.

Ten of 225 patients who were approached had to be discarded from this consideration because they were unconscious or not mentally clear. Nine of these had penetrating head wounds. If all penetrating head wounds are excluded, only one patient out of the other 201 seriously wounded patients was not alert and mentally clear at the time of examination, and, accordingly,

had to be eliminated from this study, an interesting point in the light of the puzzlingly low incidence of pain found.\*

In Table I the data are broken down into considerable detail, for those who are interested in the composition of the material on which conclusions are based. The nature of these observations is such, however, that it will be safest to confine the attention largely to the over-all effects rather than to details of questionable significance. In line with this it is interesting to observe that:

69 patients, or	32.1%, had no pain
55 patients, or	25.6%, had slight pain
40 patients, or	18.6%, had moderate pain
51 patients, or	23.7%, had bad pain
Total 215	100.0%

Naturally, a close parallelism exists between the number wanting pain relief medication and those reporting bad pain:

Bad pain reported:	
Yes.....	51 cases, or 23.7%
No.....	164 cases, or 76.3%
Pain relief therapy wanted:	
Yes.....	58 cases, or 27.0%
No.....	157 cases, or 73.0%

This close agreement of those reporting bad pain and those wanting pain relief therapy offers supporting evidence that the pain was accurately characterized.

Of the 51 patients who reported bad pain, five had had no morphine, the remaining 46 averaged 24.5 mg. for the most recent dose (compare with the average size of the most recent dose for each of the several groups), and averaged 30.5 mg. for total dose. Of the 157 who did not want further pain relief medication 32 had had no morphine, the remaining 125 averaged 27.3 mg. for total dosage. The time since the most recent dose of morphine was administered is comparable in the two groups: those who had bad pain and those who did not want further pain relief (Table I). Likewise, comparable are the total doses of morphine in the two groups. These data indicate that the patients with bad pain are not to be explained as having received less morphine or having gotten it longer ago than those who did not want further pain relief therapy.

In round numbers, the following percentages of patients in the various groups said they had bad pain:

Penetrating cerebral wounds.....	7%
Penetrating wounds of the thorax.....	12%
Extensive soft-tissue injury.....	16%
Compound fractures of long bone.....	24%
Penetrating abdominal wounds.....	48%

\* A badly injured patient who says he is having no wound pain will protest as vigorously as a normal individual at an inept venipuncture. It seems unlikely that the freedom from pain of these men is to be explained on the basis of any general decrease in pain sensitivity.

Evidence that morphine is too often given by *rote*, and not according to the pain present, is found in the fact that bad pain was reported four times as often in the penetrating abdominal wounds as in penetrating wounds of the thorax, yet there is no important difference in the quantity of morphine administered to the two groups.

Abdominal wounds, on the basis of actual records, are, thus, found to cause far more pain at the time of entry into the Forward Hospital than other wounds do. Probably this great pain is due at least in part to spilling of blood and intestinal contents into the peritoneal cavity. Perhaps infection also has a part in increasing the pain.

Three-quarters of badly wounded men, although they have received no morphine for a matter of hours (Table I), have so little pain that they do not want pain relief medication, even though the questions raised remind them that such is available for the asking. This is a puzzling thing and perhaps justifies a little speculation. It is to be remembered that these data were obtained entirely from wounded soldiers. A comparison with the results of civilian accidents would be of interest. While the family automobile in a crash can cause wounds that mimic many of the lesions of warfare it is not at all certain that the incidence of pain would be the same in the two groups. Pain is an experience subject to modification by many factors: wounds received during strenuous physical exercise, during the excitement of games, often go unnoticed. The same is true of wounds received during fighting, during anger. Strong emotion can block pain. That is common experience. In this connection it is important to consider the position of the soldier: His wound suddenly releases him from an exceedingly dangerous environment, one filled with fatigue, discomfort, anxiety, fear and real danger of death, and gives him a ticket to the safety of the hospital. His troubles are about over, or he thinks they are. He overcompensates and becomes euphoric, as Douglas Kelling has found. Whether this actually reduces the pain remains unproved. On the other hand, the civilian's accident marks the beginning of disaster for him. It is impossible to say whether this produces an increased awareness of his pain, increased suffering; possibly it does.

Evidence has been presented above that morphine has not been given with reasonable accuracy to those needing it: doses given do not adequately parallel the pain present; delayed morphine poisoning, and the not uncommon tendency of some months ago to overdose point the need for improvement in the use of morphine. If it is borne in mind that almost the sole justification for the use of morphine is severe pain, and inquiry made concerning the need of a given patient before administering it, the situation will be improved.

#### TREATMENT OF PAIN: USE OF MORPHINE

Elementary as the following points may seem to the informed, constant repetition of them was found to be necessary:





*Administration.*—a. Dosage. Nearly the maximum analgesic effect of morphine is produced by smaller doses than generally supposed: Morphine  $\frac{1}{4}$  gr. (15 mg.). Larger doses chiefly cause undesirable side-effects. They impair the body's power to overcome adverse situations. Usually morphine is not to be administered in greater than  $\frac{1}{4}$  gr. (15 mg.) single dose. Use only small doses in patients to be transported by air,  $\frac{1}{8}$  gr. (8 mg.) to  $\frac{1}{6}$  gr. (10 mg.). Respiratory depression here is particularly undesirable (allay apprehension and fear of the first ambulance plane flight with barbiturates).

b. Route. Subcutaneous or intramuscular injection is employed when a gradual, prolonged effect is sought. This route is avoided when the peripheral circulation is slowed by cold or low blood pressure (see discussion below of delayed morphine poisoning in battlefield casualties). A better choice in such cases is intravenous injection. This is the best route also when immediate pain relief is wanted, or when delayed absorption might prove harmful, as in anticipated or developing shock. When injection is impossible (no syringe) morphine  $\frac{1}{4}$  gr. (15 mg.) may be held under the tongue until it is dissolved.

*Indications.* The only really important use for morphine is to relieve severe pain. Use aspirin or codeine for mild pain. In the absence of respiratory depression, head or chest wounds do not contraindicate the use of small doses of morphine, if these or associated wounds cause pain. The use of morphine in preanesthetic medication has been greatly overdone.

*Contraindications.* a. Morphine will not be used as a sedative for "the jitters" or for "nervousness," in manic or hysterical states, for allaying fear, for promoting sleep (unless pain is present). Such use cannot be defended. For these conditions better agents are available (phenobarbital or pentobarbital sodium or paraldehyde). Neither is morphine to be used for controlling the restlessness associated with hemorrhage.

b. Morphine will be avoided (except where pain is present) as a routine agent in the preanesthetic medication of seriously wounded patients. Anesthesia is usually easy to induce in them, in any case.

c. Morphine will not be administered in the field to a patient who must walk back to the Aid Post. At the Aid Post it will not be given to the wounded man who must at once be evacuated to the rear as "walking wounded." Such may become confused, lie down along the evacuation route, and go to sleep. Evidence is accumulating that nausea following morphine administration is more frequent and more severe in ambulatory patients than in patients at rest lying down.

d. Morphine is contraindicated in shock unless pain is present. (See description below of effects morphine has on the respiration, circulation and fluid balance.)

e. Morphine is widely recognized to be dangerous in conditions of low metabolism, as in hypothyroidism.

f. Morphine is largely destroyed in the liver; therefore, it should be

used with great caution, if at all, in the presence of liver disease, as infectious jaundice.

g. Morphine will be used with great caution, if at all, when even minor degrees of anoxia might be dangerous, as in circulatory impairment, or when the respiration is already impaired, as by pneumothorax, hemothorax, or pleural effusion, when mechanical obstructions of the air-way are present or when central depression exists, morphine is ordinarily contraindicated.

*Poisoning.* This is first characterized chiefly by slow respiration and pin-point pupils. The outstanding serious effect of overdosage with morphine is respiratory depression, with anoxia. This is followed by circulatory damage. Less severe poisoning than the above, even therapeutic doses, often complicate treatment of the patient: morphine, in causing anorexia, nausea and vomiting, limits the intake of food and fluids by mouth and increases fluid loss in vomitus and sweat. Severe constipation is produced.

*Delayed Morphine Poisoning in Battle Casualties.* a. When the peripheral circulation is sluggish or inactive, as it may be in patients who are chilled or who have low blood pressure, subcutaneous injections of drugs are poorly absorbed. This was frequently observed to be the case in the Italian campaign.<sup>1</sup> Subcutaneous injection of morphine, under circumstances where absorption fails, does not relieve the pain of wounded men. Repeated injections, sometimes over a period of many hours, are not absorbed until finally, by shock therapy and warmth, the circulation is reestablished in the skin and subcutaneous regions. All of the unabsorbed deposits of morphine are then taken up by the active circulation so rapidly that signs of morphine poisoning previously not present then appear, as shock is overcome.

b. Although the intravenous use of morphine is desirable and would eliminate the problem, such use is not ordinarily practicable under outside field conditions. In this case, intramuscular injection followed by massage is the choice. All morphine injections should be made low enough on an extremity so that a tourniquet can be placed proximal to them if poisoning develops. Care is to be exercised in recording dose used, time given, and site of injection.

*Treatment of Morphine Poisoning.* Realization that morphine intoxication may have a rather abrupt onset many hours after the last morphine injection, under the circumstances discussed above, is a considerable help in recognizing the problem at hand. Correct diagnosis leads to prompt and effective treatment. A tourniquet, intermittently loosened, is placed proximal to the site of the injection. Primarily, the treatment of morphine poisoning consists in the effective prevention of anoxia. This is best accomplished by oxygen administration, with artificial respiration (if necessary) easily carried out with the aid of a closed anesthesia apparatus by means of intermittent bag pressure, with carbon dioxide absorption. Atropin  $\frac{1}{60}$  gr. (1 mg.) intravenously may be of value. Ephedrine  $\frac{1}{2}$  gr. (30 mg.) intravenously has some value as a central stimulant. It may help to support a falling blood pressure. Hypertonic glucose intravenously is a good diuretic and aids in

excretion of morphine by the kidneys. Body heat should be conserved. If coma develops, a gastric tube should be inserted in order to eliminate the possibility of aspiration of gastric contents. Moreover, frequent change of position is of value in reducing the later appearance of pulmonary complications. The treatment is supportive while the morphine overdose is largely destroyed in the body.

#### TREATMENT OF PAIN: MISCELLANEOUS MEANS

*Regional Nerve Block.* Various appropriate regional nerve blocks are of use. Outstanding here is the use of intercostal or paravertebral nerve block for controlling the pain of chest wall injury. This is followed by pulmonary ventilation more nearly normal in character. These blocks are so easily and quickly carried out, and afford such striking relief, it should be widely used. The usefulness of the local injection of procaine in the presence of some sprains is well-established.

*Proper Splinting and Bandaging.* The need for adequate wound support is so obvious as to require little comment, yet a common needless cause of severe pain is the swelling of the lower leg and foot in the case of fracture of the long bones of the extremity. The shoe should always be unlaced and slit if left on. Failure to observe this has led to many hours of acute suffering in patients who get prompt relief when this is done.

#### EMOTIONAL FACTORS AS WELL AS PAIN REQUIRE TREATMENT

The circumstances that have led to the wound may have been associated with anxiety; with emotional stress; with grief from the loss of friends; with fear; and these have often been exaggerated by the sights and sounds of prolonged combat, coupled with the physical discomforts of exposure to the weather, inadequate food and fluid intake, loss of sleep, exhaustion, as well as by pain. On top of all this the newly wounded man suddenly has to face the consequences of his wound: His arm is injured—will he lose it? There is blood around his genitals—will he be impotent? That wound in his chest—is he going to die? Given half a chance, indications of great mental agitation come out in a rush, from men who have been lying quietly, often seemingly asleep. Others react to this inner turmoil by restlessness and occasionally by manic states. (See the case referred to below.)

It is unlikely that lives are lost by the busy medical officers disregard of these mental and emotional factors at this early period in the patients' care; but what effect such disregard will have on the patient's later course has not yet been adequately considered. Thoughtful discussion of their cases with a few wounded men in any preoperative ward will show that much needless suffering results from neglect here. Neglect of these emotional problems at this time may have a profound effect on the patient's attitude toward his wound and to return to duty. Important from the military viewpoint is the inescapable fact that the patient's permanent outlook is powerfully and lastingly influenced by events at this time. Examples: The un-

warranted lighthearted statement by a medical officer that the patient will go home now that he is wounded, although later proven untrue, has done its damage, and it becomes in many cases impossible to reestablish the qualities of a good combat soldier in the healed patient. A disease labelled "shell shock" is often incurable; whereas if it be called merely exhaustion, a good response to treatment is obtained, *etc.* The early hours after wounding are important for establishing a point of view in the patient that will be of help in his early return to duty. More study of this period by psychiatrists is needed.

Part of the difficulty with the treatment of the distress of the wounded is that morphine is often employed in an attempt to treat conditions that will not respond to it however large the dose.<sup>2\*</sup> Patients are described as "writhing in pain," and large doses of morphine administered when the real problem is restlessness from cerebral anoxia, or excitement from fear and apprehension. In the former case correction of the oxygen shortage, in the latter, sedation, as with barbiturates, is indicated, not morphine.

Certainly, no one wishes to minimize the importance of adequate pain therapy (morphine): but there is too little realization that treatment of the actual pain present is only part of the job to be done. Wounded men need sedatives of the barbiturate type as well as narcotics. At times *small doses of both types of agent will accomplish what large doses of either alone will fail to do.*

Use of barbiturates in treating the agitation encountered in the wounded is illustrated by the following example:

**Case Report.**—A husky 19-year-old soldier was wounded at the Anzio Beachhead by a mortar shell. Five hours later he was brought into the nearest hospital with a meat cleaver-like wound cutting through the fifth to 12th ribs near the vertebral column. He had bled a great deal (hemoglobin 9.5 Gm.; not yet completely diluted) and was cyanotic. Obsessed with the idea that he was lying on his rifle, he constantly struggled to get off the litter and complained bitterly of the "pain." Three attendants were necessary to keep him on the litter. Examination of the patient in any adequate sense was impossible. He appeared to be wild from pain. His wound supported such a belief. (Not only were eight ribs cut in two, and an open pneumothorax present, but later it was found that the lower lobe of the lung, the diaphragm, and one kidney had been lacerated by a broken rib end.) He had had no morphine for at least four hours, and it was planned to give him more; but since the situation was confused, it was decided to give him 150 mg. (2.5 gr.) sodium amytal by vein. This was done, and he at once quieted down and went to sleep. Obviously no morphine was needed.

The patient was rousable but remained quiet for the next hour, until he went to the operating room. During the quiet period he was examined, and catheterized, previously impossible, and found to have grossly bloody urine. Immediately after receiving the barbiturate his color improved strikingly, doubtless in part due to the cessation of great physical exertion and to the fact that instead of constantly yanking out his nasal oxygen tube, it stayed in place, and his blood pressure rose at once from 60 up to 80 mm. Hg., systolic. Before the barbiturate was given all agreed that the patient's condition was rapidly deteriorating; he turned for the better immediately after the

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\* A common error in civil medicine as well as in warfare.

amytal was given. The dose given would not have controlled pain. It is reasonable to conclude that his manic state was not due to pain.

In the group of patients that received a sedative during the course of this study, sodium amytal was used intravenously, not from choice but because it was the only barbiturate available at the time for intravenous use. Had it been available nembutal sodium would have been used. Whenever sedatives are employed in the wounded, it must be remembered that depleted, bled-out individuals, men in shock, appear to be extraordinarily sensitive to these agents. It is best not to exceed at a given time a single dose of one grain (60 mg.) of sodium amytal for intravenous use in such patients. This can be repeated after 15 or 20 minutes.

#### THIRST

The data contained in Table I are based entirely on men who, although severely wounded, were not in shock. In these men thirst often causes considerable distress; but on the basis of records kept on 50 of these patients it is nearly always less a cause of discomfort than the wound. In the case of men in traumatic shock thirst rises to first place as a cause of suffering. Men in shock complain bitterly of thirst; they much less frequently complain of pain.

The administration of fluids by mouth is undesirable in patients who are soon to be anesthetized. Some relief is given by sponging-off the lips and by mouth rinses. Correction of the thirst requires restoration of the depleted blood volume, best achieved by intravenous fluid therapy.

Considering the amount of suffering caused by thirst in the badly wounded, it is curious that so little attention has been paid to ways of minimizing this symptom.

#### SUMMARY

Severe wounds in soldiers are often associated with surprisingly little pain. In order to get factual information on the incidence of pain, 225 freshly wounded soldiers were considered in five groups where the wounds were serious—compound fractures of long bones; extensive peripheral soft-tissue wounds; penetrating wounds of the thorax; penetrating wounds of the abdomen; and penetrating wounds of the cerebrum. None of these men was in shock at the time of questioning. As nearly as possible consecutive cases were considered. Ten of these had to be eliminated from consideration here because they were not clear mentally, or were unconscious. Nine of these ten had penetrating head wounds. If the head wound group is entirely disregarded, only one patient out of the remaining 201 severely wounded was not alert and clear mentally.

Of the various types of wounds considered, patients with penetrated abdomens have by far the most pain, possibly due to the spilling of blood and intestinal contents into the peritoneal cavity. Of all the patients considered only one-quarter, on being directly questioned shortly after entry in a

Forward Hospital, said that their pain was enough to cause them to want pain relief therapy; three-quarters did not need such relief. This was the case notwithstanding the fact that the most recent morphine had been administered hours before (Table I). Evidence is presented to show that the difference between the one-quarter that wanted pain relief therapy and the three-quarters that did not, cannot be explained by differences in dosage or timing of the morphine administered. Data are presented to show that morphine is too often administered by *rote* and not according to the patient's need. The data carry the strong implication that morphine is too often used in the belief that severe wounds are inevitably associated with bad pain—clearly not the case. The use of morphine in the treatment of pain is considered in detail.

It was observed that the excitement and hyperactivity occasionally encountered in the wounded had its origin in some cases not in pain but in cerebral anoxia, and more commonly in mental distress. Use of a small dose of a barbiturate provided great relief in the latter type of case. A small dose of a barbiturate in addition to a small dose of a narcotic will accomplish what large doses of either alone will often fail to do. Barbiturate sedation offers a real addition to the treatment of the wounded man. He often needs the type of mental depression produced by barbiturates in small dose as much as he needs the pain depression produced by morphine.

The man in shock complains far less frequently of wound pain than he does of the great distress produced by thirst.

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# RETROPERITONEAL (MESENTERIC POUCH) HERNIA

## CASE REPORT

BRIG. GEN. I. S. RAYDIN, U.S.A.

AND

LT. COL. PHILIP J. HODES, M.C., A.U.S.

THE CORRECT DIAGNOSIS, and the successful surgical treatment of an unusual intra-abdominal hernia is of sufficient rarity to record it. The case is all the more interesting since the primary anomaly was associated with a secondary one—a giant Meckel's diverticulum. The history was unusual in that it suggested the presence of a duodenal ulcer and recurrent intestinal obstruction. The roentgenographic findings were indeed bizarre.

**Case Report.**—A 29-year-old soldier was admitted to a General Hospital in Assam, March 15, 1944, with a chief complaint of upper abdominal pain. He had been in excellent health except for indigestion until March 2, 1944, when he developed malaria. He received antimalarial therapy and was returned to duty March 12, 1944.

On March 13, 1944, he developed sudden acute pain in the right upper abdomen. He was nauseated but did not vomit. The pain, which was sharp and intermittent, began gradually to subside after one hour, and within 24 hours he was comfortable. Following recovery he was hospitalized for study.

The past medical history was not remarkable. He had just recovered from malaria and had not completely regained his strength. He had never previously had abdominal pain of the type recently suffered, but he had had a long history of "indigestion," and postprandial distress.

Physical examination revealed a well-developed Negro soldier whose sclera were tinted a lemon-yellow, presumably from the atabrine. The heart and lungs were negative to auscultation and percussion. The abdomen was not distended and no unusual tenderness was present, nor were any definite masses palpated.

Temperature and respiration were normal, red blood cell count was 3,150,000; the hemoglobin 6.5 Gm. per 100 cc.; and white cell count 5,600. The Kahn was negative. There was no evidence of sickling of the red cells. Two stools were positive for occult blood.

On March 23, 1944, while in the hospital, the patient had a second attack of sharp intermittent right upper quadrant pain similar to that which he had suffered ten days previously, except that this time he vomited. It developed soon after breakfast and was severe. It was mainly in the epigastrium and right upper quadrant, and the area remained hyperesthetic following subsidence of the acute pain.

Following recovery from this attack roentgenologic studies were made. The first gastro-intestinal series revealed a normal stomach. There was slight duodenal irritability which was considered reflex in origin. An air and fluid level was seen fluoroscopically in the region of the hepatic flexure of the colon (Fig. 1). Because of this a barium enema was introduced. This disclosed an anomaly in the ascending colon and hepatic flexure. The latter was depressed and shifted medially. The ascending colon lay close to the spine. There was no evidence of an obstructing lesion of the colon. The air and fluid level was easily identified above the hepatic flexure in the region of the gallbladder. The gallbladder was found to be normal by cholecystography.

A small intestinal study, using distilled water and barium, was then made. Fluoroscopic examination of the small intestine 30 minutes after the study was begun, revealed the head of the barium column in the region of the midileum. It was seen just entering

# RETROPERITONEAL HERNIA

the gas-filled shadow (Fig. 2). The afferent ileal loop ascended from its normal position in the lower abdomen into the right upper quadrant. In this area the barium seemed to spill across a kinked portion of the intestine into a dilated loop of ileum, which was the site of the air and fluid level (Figs. 3 and 4). Manipulation of the bowel, under fluoroscopic guidance and changing the patient's position, suggested that the ileum was fixed in this abnormal position. It was obvious

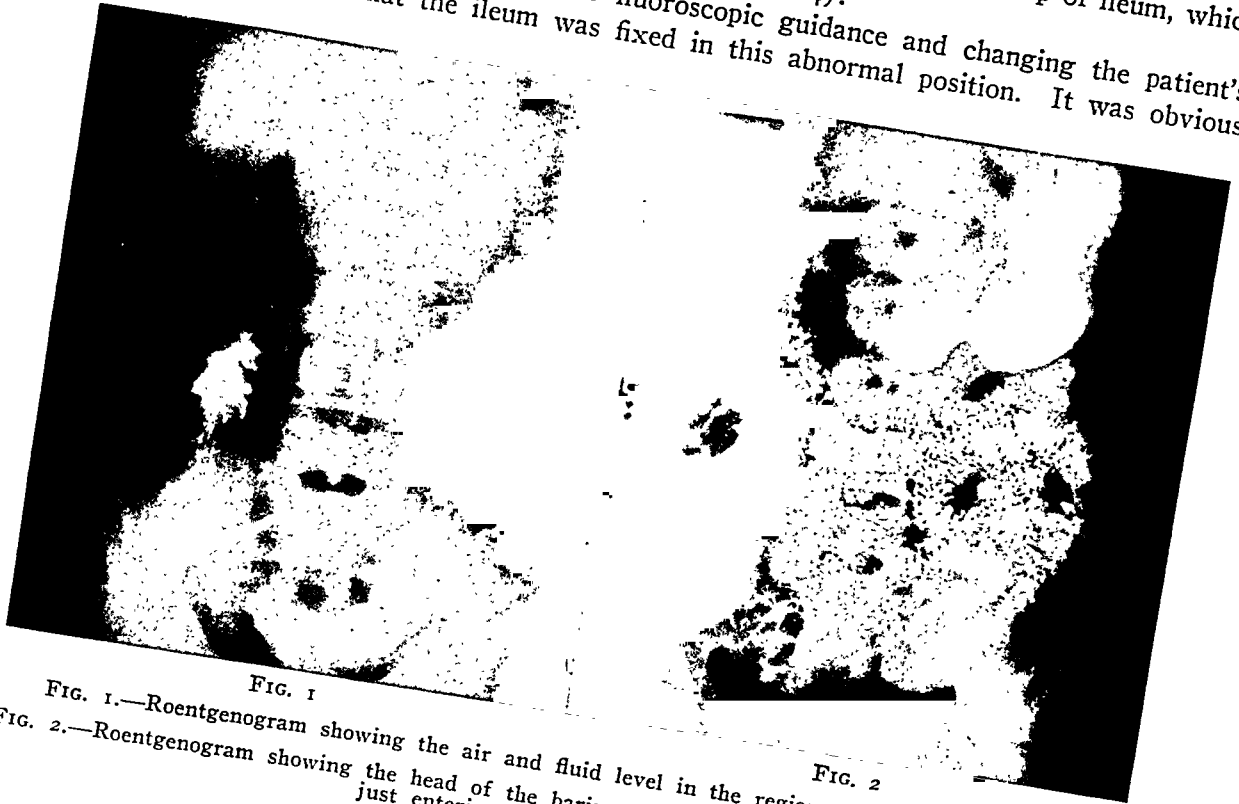


FIG. 1.—Roentgenogram showing the air and fluid level in the region of the hepatic flexure.  
FIG. 2.—Roentgenogram showing the head of the barium column in the region of the midileum, and just entering the gas-filled shadow.

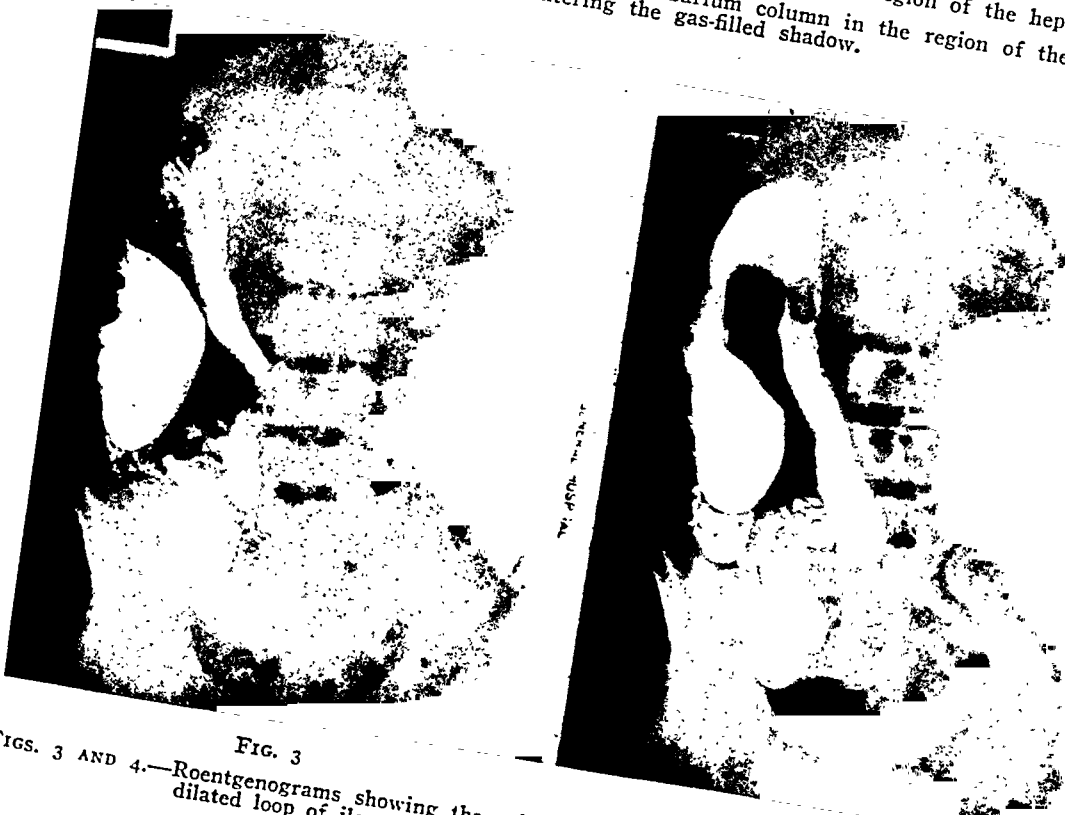


FIG. 3  
FIGS. 3 AND 4.—Roentgenograms showing the spillage across a kinked portion of the intestine in the dilated loop of ileum, which was the site of the air and fluid level.



that this was the site of an incomplete intestinal obstruction with proximally dilated ileum. The peculiar tense contour of the barium-filled bowel strongly suggested that the loop was enclosed in a membrane or sac. The picture was compatible with the presence of an intra-abdominal hernia, and suggested, in addition, a large dilated Meckel's diverticulum. *Roentgenologic Conclusions:* Partial small intestinal obstruction associated with an intraperitoneal hernia, which also includes a greatly enlarged Meckel's diverticulum.



FIG 5.—Photograph showing the giant Meckel's diverticulum exposed upon opening the sac.

*Operation.*—April 28, 1944: An exploratory celiotomy was performed under continuous spinal anesthesia. Right paramedian incision. Surrounding the lower ileum was a translucent peritoneal sac which seemed to constrict the small bowel, for the small bowel proximal to the entrance into the sac was dilated and thickened. The sac was opened and a giant Meckel's diverticulum was exposed (Fig. 5). The diverticulum was bound down to the right posterior lateral abdominal wall behind and above the hepatic flexure of the colon. The small bowel from proximal to the diverticulum was also greatly dilated. The sac containing the small bowel and diverticulum seemed kinked on itself and rotated to the right.

The sac was widely opened and the structures more clearly identified. The bowel, from a distance 5 cm. proximal to its entrance to the sac and an equal distance distal to its emergence from the sac, was freed from all surrounding attachments. The entire area of bowel, including the sac, was then excised and intestinal continuity reestablished by end-to-end anastomosis (Figs. 6 and 7). All parietal denuded areas were carefully peritonized. Ten grams of sulfanilamide crystals were placed in the peritoneal cavity and the wound closed by layer suture.

*DISCUSSION.*—The hernia involved the distal portion of the ileum, there being not more than 30 cm. of small bowel from the point of exit from the sac to the ileocecal valve. The sac was thin, nearly transparent, and was avascular.

It is obvious that the lesion belonged to the general group classified as retroperitoneal or intraperitoneal herniae. Originally considered to have been

# RETROPERITONEAL HERNIA

FIG. 6

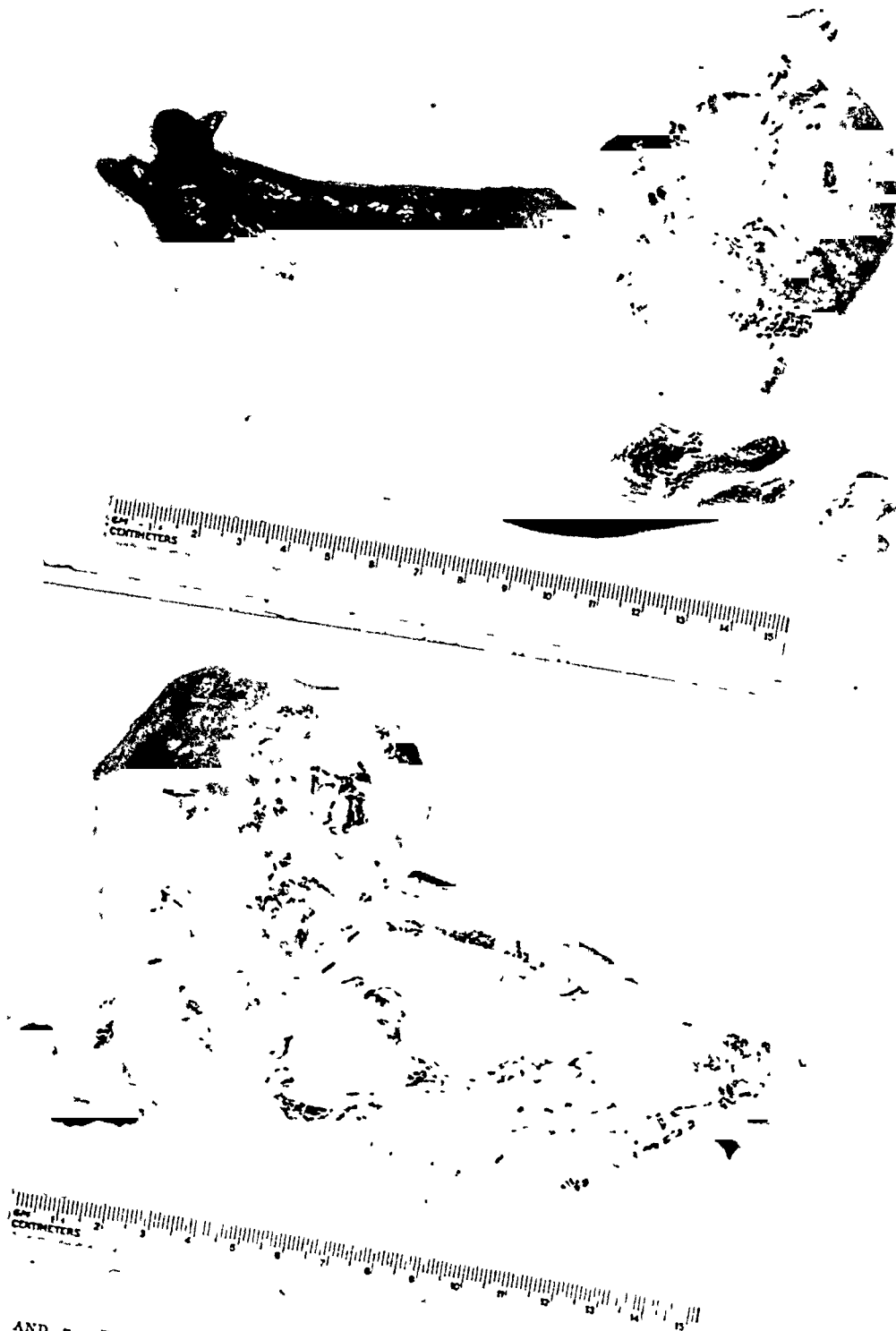


FIG. 7

FIGS. 6 AND 7.—Photographs showing the anterior and posterior aspects of the gross specimen, consisting of the entire area of bowel, including the sac, which was excised.

herniations into intraperitoneal fossae, especially the duodenal fossae, they are now generally accepted as being due to developmental defects. Andrews<sup>1</sup> has shown these herniations to be the result of "imprisonment of the small intestine beneath the mesentery of the developing colon." Callender, Rusk and Nemier<sup>2</sup> have confirmed Andrews' concept, and have suggested that an hernia such as the one being reported be called "hernia behind the ascending mesocolon." The recent report by McCarty and Present<sup>3</sup> would tend to confirm these conclusions.

The trapped portion of the ileum lay behind a mesenteric veil of the ascending colon which formed the sac. No large blood vessels were encountered either at the entrance or exit from the sac, as is usually the case. This was a happy circumstance, for it permitted of resection without danger of interfering with the blood supply to the remaining intestine.

It must be presumed that in the primary rotation of the intestine and the subsequent movement of the large bowel to the right and downward, the involved bowel became imprisoned between the mesentery of the colon.

The history suggestive of duodenal ulcer and intestinal obstruction is not unusual, although in numerous instances the lesion causes no gastro-intestinal symptoms. One such lesion, reported by Addinell Hewson some years ago, was discovered by one of us at the dissecting table. Those that give rise to symptoms must be treated surgically, the exact operative procedure depending upon the findings at operation. There can be little doubt but that the large Meckel's diverticulum was the major cause of the obstructive phenomena. The patient here reported made an uneventful recovery and has remained symptom free, and on full duty.

#### SUMMARY

An instance of retroperitoneal hernia is reported. It was unusual in that it involved only a limited portion of the ileum and, also, that the sac was avascular and no large blood vessel was present at either the entrance or exit from the sac. In addition, there was present a giant Meckel's diverticulum which was the cause of the patient's obstructive symptoms. Complete resection and anastomosis has resulted in recovery and relief from all symptoms.

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# CYSTIC DISEASE OF THE LIVER

## REPORT OF A CASE

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CYSTIC DISEASE of the liver, cystic liver, cystic degeneration of the liver, polycystic disease of the liver and congenital cysts of the liver are terms used to describe the presence of numerous nonparasitic cysts, of varying size, occurring in the liver.

Multiplicity of the cysts, according to Rolleston,<sup>1</sup> and Weiss,<sup>2</sup> serves to distinguish cystic disease from the condition of a simple solitary cyst, often referred to as a retention cyst. This difference may be only apparent, as it has been suggested that a solitary cyst may be the end-product of cystic disease, wherein, because of growth and pressure, the contiguous walls of the multiple cysts disappear, thus forming a large, unilocular structure. Surgically speaking, however, the difference can be considered real. Simple solitary cysts are localized, are usually circumscribed and occasionally possess a pedicle. The result is that surgical treatment of solitary cysts is far more often possible than in cases of cystic disease, wherein the lesion is more generalized with reference to the liver. Marsupialization, for example, can be accomplished with fewer technical difficulties in a case of simple cyst than would be possible in a case of cystic disease. If surgical treatment is undertaken at all in cystic disease, extirpation of the involved region is usually necessary, in which case the technical difficulties are considerably increased.

**Case Report.**—A white male, a blacksmith and welder, age 39, was first seen at the Mayo Clinic on August 9, 1944. His family history was noncontributory to his present illness. In 1924, he had been told that he had chronic lead poisoning but, when he was questioned concerning this, he was unable to remember much about it. In 1927, tonsillectomy had been performed.

The patient's chief complaint was a feeling of fullness and dull aching in the epigastrium. This distress had been present for four years and was progressively becoming worse. He associated the onset with an upper respiratory infection, following which he had noted a very mild sense of fullness in the abdomen. Shortly after the onset, he began to associate this sense of fullness with the taking of meals. Almost immediately after taking of food, he would experience pressure and aching in the epigastrium, which would last for about two hours and gradually subside. It was at this time, also, that he became aware of an increase in the size of his epigastrium, also following the ingestion of a meal. Except for the two hours of discomfort following a meal, the intervals between the taking of food were symptomless. About three years ago he noted that the increase in size of his epigastrium persisted whether or not food was taken. The symptoms progressed until at the time of his examination at the

Clinic he was aware of a large mass in the epigastrium and was unable to ingest even a moderate amount of food without feeling discomfort. Also, in addition to the sense of fullness and pressure in the epigastrium, he was then experiencing nausea after meals. There was no history of loss of weight; his appetite was good; there never had been any vomiting nor diarrhea and he was unable to recall that he had ever had any tarry or bloody stools. A systemic inventory elicited no additional complaints.

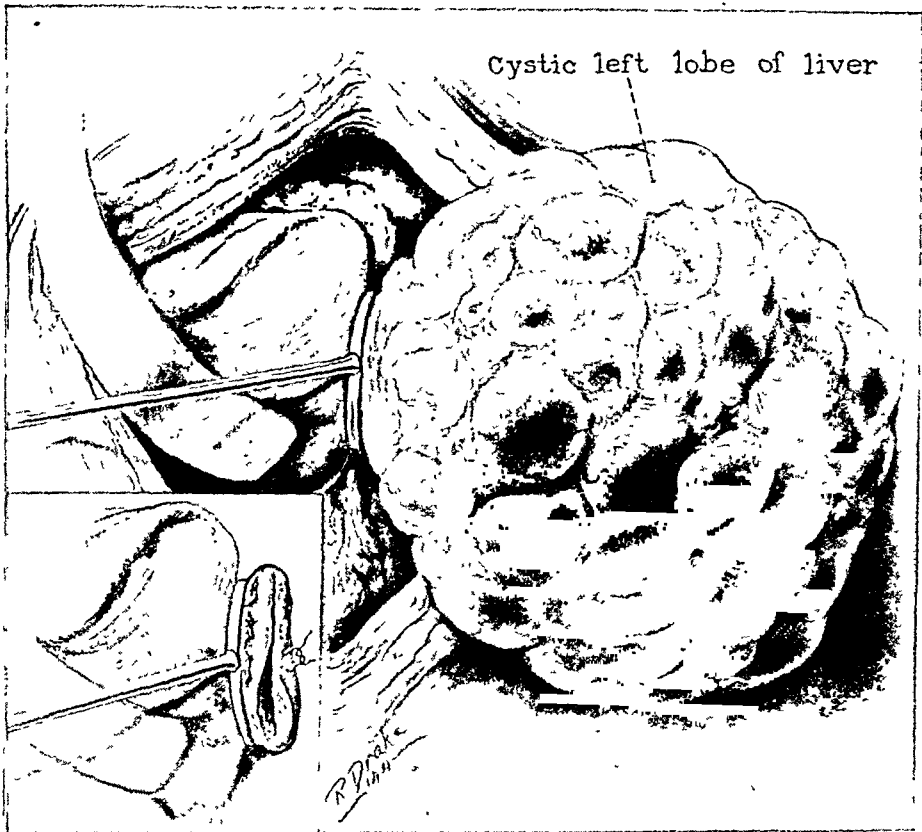


FIG. 1.—Left lobe of the liver involved by cystic disease; tourniquet applied around its pedicle. Inset: Removal of left lobe of liver and closure of pedicle with interrupted mattress sutures.

On physical examination, the patient appeared to be in excellent health. His normal weight was between 185 and 190 pounds (83.9 and 86.2 Kg.). His weight at the time of the examination was 180 pounds (81.6 Kg.). When he was in the recumbent position a swelling could be seen in the epigastric region. On palpation, the swelling seemed to be a cystic tumor with an irregular surface. Except for bilateral nerve deafness, other physical findings fell within normal limits.

The routine laboratory findings were within a normal range. A roentgenogram of the stomach showed the presence of a large extrinsic mass, the stomach itself being normal.

It was thought that the patient might have a pancreatic cyst. Accordingly, the concentration of sugar in the blood was tested. It was found to be 112 mg. per 100 cc. of blood. The blood amylase was 160 units and the lipase was negative. The serum bilirubin was within a normal range. The dye test of liver function showed no retention of the dye. In spite of the normal results obtained in investigating the pancreatic function, it was thought that the epigastric tumor was probably a pancreatic cyst.

Accordingly, on August 12, 1944, operation was performed through a primary

## CYSTIC DISEASE OF THE LIVER

upper left rectus incision. Immediately, a portion of the mass, consisting of multiple various-sized cysts, presented itself into the incision. On further examination it was found that this represented the left lobe of the liver. Examination of the right lobe showed it to be normal in appearance. Palpation of both kidneys was then done and neither seemed to be cystic. By separating numerous adhesions from the mass, a rela-

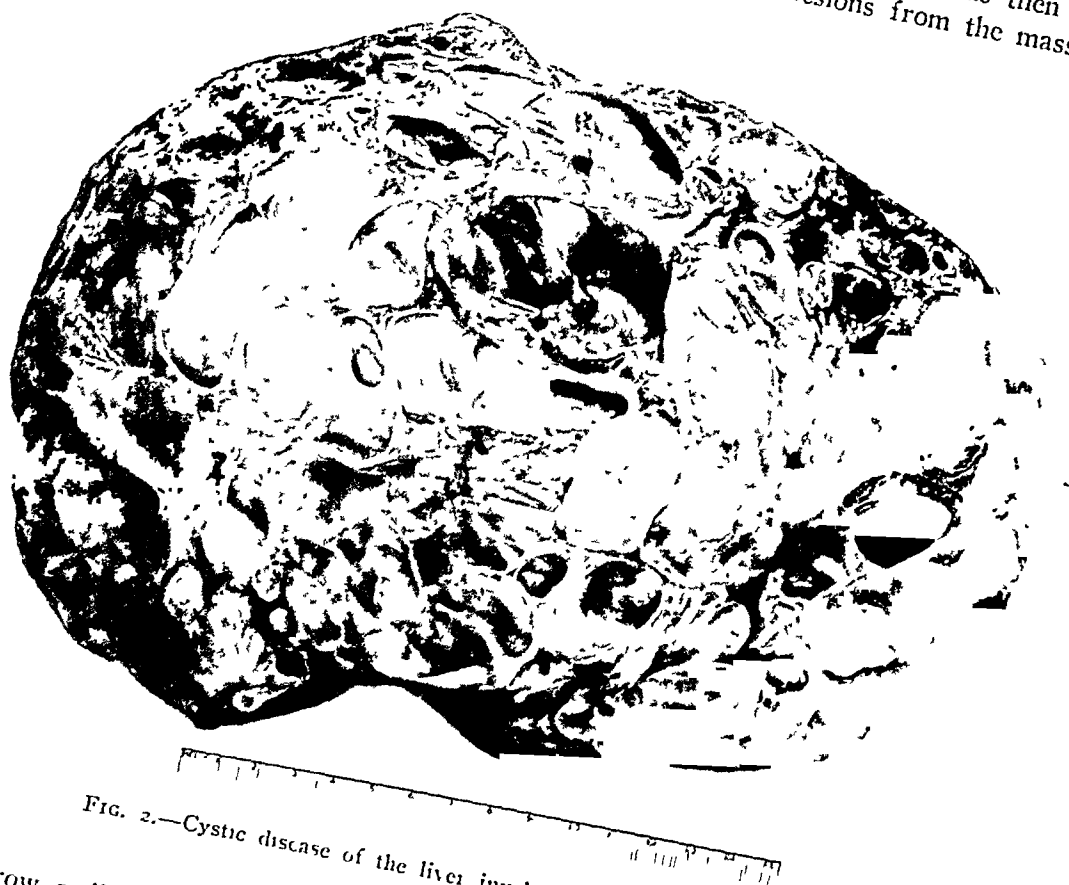


FIG. 2.—Cystic disease of the liver involving the entire left lobe.

tively narrow pedicle was encountered adjacent to the ligamentum teres. A Bethune pneumonectomy tourniquet was then applied around the pedicle (Fig. 1) and the entire left lobe of the liver was removed *en masse*. The remaining stump was closed with interrupted chromic catgut sutures. The tourniquet was then removed and there remained only minor oozing of blood from the stump. It was feared, inasmuch as the entire hepaticoduodenal and gastrohepatic ligaments were exposed in the procedure, that injury might have occurred to the common and hepatic bile ducts. Examination, and later clinical recovery, showed that no injury had occurred.

Five grams of sulfanilamide powder was sprinkled into the area and one double iodoform pack was placed to control what oozing might occur from the stump. Two Penrose drains were brought out through the incision.

The pathologist who examined the specimen stated that it was the entire left lobe of the liver (Fig. 2), weighing 1,005 Gm., and consisting of multiple cysts lined by epithelium of bile duct type (Fig. 3). The cysts varied from 8 cm. in diameter to those of microscopic size.

The postoperative convalescence was uneventful. On the eighth postoperative day, the gauze pack was removed. On the ninth day the patient was permitted to be up. The Penrose drains were removed, one on the tenth day, the other on the 11th day. The patient was dismissed from the hospital on the 13th postoperative day and was permitted to return to his home on the 15th postoperative day.

## COMMENT

In addition to the fact that the left lobe of the liver was removed, this particular patient presented several interesting features. Involvement of the left lobe by nonparasitic cysts occurs much less frequently than involvement

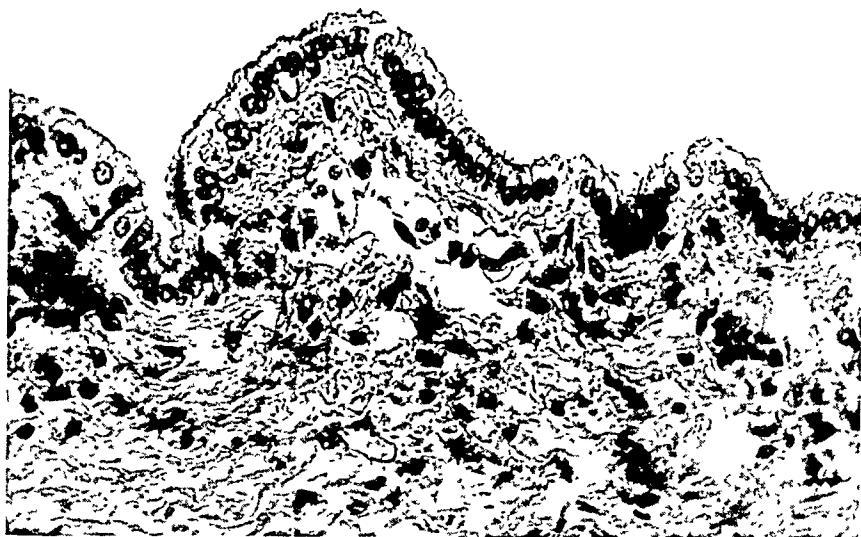


FIG. 3.—Bile duct epithelium lining the cystic cavities.

of the right lobe. McCaughan and Rassieur,<sup>3</sup> in reviewing 80 such cases, including two of their own, found that 52 patients had cystic tumors in the right lobe, 11 in the left and two in the middle lobe. In six cases the entire liver was cystic. In nine cases the position was not mentioned. As will be discussed later, cystic disease of the liver is usually associated with cystic disease of the kidneys. This did not prove to be true in this case.

The general incidence of cystic disease is low. Ackman and Rhea<sup>4</sup> stated that 11 cases of nonparasitic cysts were found in 6,141 necropsies.

A recent and extensive review of the literature was made by Davis,<sup>5</sup> in 1937. He was able to gather data on 499 cases of nonparasitic cysts of the liver, including one of his own. In only 241 of these 499 cases were there multiple cysts or cystic disease. In the remaining cases the cysts were reported as being solitary and unilocular (187), solitary and multilocular (20), or unstated (51). Other reporters found a similar proportion to exist in the cases reviewed by them.

The age incidence shows the disease to be rarely discovered in infants and the newborn. Rolleston<sup>1</sup> suggested that there may be some discrepancy in these findings because the disease is doubtless overlooked, since the involved liver in the newborn suggests fibrosis rather than cystic disease. He also suggested that since some cases have been associated with unrelated malformations, polydactylism, meningocele, *etc.*, a routine microscopic examina-

tion of the liver in these cases would show that cystic disease is less rare than is now believed.

Since it is possible for cystic disease to be present and the condition to be compatible with good physical health, in most of the cases in the literature the patient was reported to be an adult. In the cases reviewed by McCaughan and Rassieur<sup>3</sup> the average age was 33 years.

The disease occurs more frequently in the female than in the male, the ratio being three females to one male.

Most authors agree that the cause of the simple solitary cyst is some form of local obstruction in the biliary tract with a resultant retention type cyst. In cystic disease, however, opinion seems to be divided, since there are various hypotheses as to the pathogenesis. Four of the most prevalent will be discussed.

#### HYPOTHESES AS TO PATHOGENESIS

1. *Inflammatory*.—Mihalkowicz, Juhel-Renoy, Babinsky and Blackburn<sup>6</sup> described the process as being due to pericholangitic inflammation leading to biliary cirrhosis with dilatation of the bile ducts. The inflammatory process during fetal life weakens the walls of the small bile ducts and they dilate, never to recover their normal size.

2. *Degeneration*.—Pye-Smith<sup>7</sup> regarded the process as due to vacuolation of the hepatic cells, which then fuse with other similarly affected cells, leading to the formation of cysts. Pilliet<sup>8</sup> regarded cystic disease as being the result of atrophy of the hepatic cells, which change into new bile ducts, which, in turn, develop into cysts.

3. *Tumor Hypothesis*.—Sabourin<sup>9</sup> held that the cysts were cavernous biliary angiomas and regarded them as due to irritation, which leads to development of newly formed bile ducts; the latter fuse and dilate, forming larger cysts by a breakdown of the separating septa. Others have held that the condition was cystic sarcoma and adenoma or a cystic fibro-adenoma homologous to an ovarian cystadenoma.

4. *Developmental Hypothesis*.—This regards the condition as being congenital. Still<sup>10</sup> suggested a malformation of some of the cells of the hepatic diverticulum in the embryo. These cells then go on to form cysts. Moschcowitz<sup>11</sup> described aberrant bile ducts in the fibrous tissue of the portal spaces of cystic livers, which were not present in normal livers. He, likewise, noted the presence of these structures in livers in cases in which the kidneys were polycystic. Moolten<sup>12</sup> regarded the entire process as being due to an immaturity of development and a fixation of differentiation. He cited Lewis as showing that in fetal growth in the 28-mm. embryo the perilobular bile ducts normally arise from the hepatic cords aligned along the outer surface of the periportal mesenchyme. The ducts thus formed are seen to connect freely with the hepatic trabeculae and also to intercommunicate, thus forming a plexus. With the further growth of the liver, however, the anastomoses normally become less numerous. In the liver examined microscopically by



Moolten, that of an eight-day-old infant that died of polycystic disease, he saw it to be similar to that seen in early embryonic life, even to the point of showing the presence of different heights of the epithelium lining the ducts. Thus, where the ducts were adjacent to the parenchyma, the epithelium was of a low cuboidal type; where they made contact with the periportal connective tissue, the epithelium was of a high cuboidal type. This, according to Lewis, is normal in the embryo. Other embryonal structures seen to persist in the liver examined by Moolten were: (1) The abundance of mesenchyme in the form of abnormally thick connective tissue in the portal fields; (2) numerous large caliber branches of the portal vein; (3) dilated and ramifying collecting bile ducts with numerous unfoldings of their lining epithelium surrounded by a dense connective tissue; and (4) portal fields, which varied greatly in size and which were totally irregular in distribution.

Grossly, in the adult the liver affected by cystic disease is fairly typical. The affected portion is usually enlarged and deformed by the presence of numerous cysts of varying sizes occurring on the surface. The cysts are surrounded by a capsule of well-formed fibrous tissue and are of varying shades of glistening blue. On section, the involved region is honeycombed by multiple independent cavities. The residual hepatic tissue is seen to be decreased, depending on the size and the number of cysts. If the cysts are opened, they usually contain clear albuminous fluid, which may be brown as the result of hemorrhage. They never contain any bile.<sup>1</sup>

Microscopically, if the patient is an adult, the cysts are large and are surrounded by well-formed fibrous tissue. The epithelium lining the cysts varies with the size, and therefore the stage of development, of the cyst. Thus, in the larger type, the epithelium may be degenerated, absent or represented by a few flattened cells. In the medium-sized type it is cuboidal, and in the smaller cysts, columnar. Usually the hepatic cells are well-preserved.

All authors reviewed make special mention of the fact that cystic disease of the liver is usually associated with cystic disease elsewhere—notably in the kidney. When there are associated renal lesions, they are usually far more advanced than those that occur in the liver.

Moschcowitz reviewed 85 cases of cystic disease of the liver and in only ten did he find that the liver alone was affected. The converse, however, is not true, inasmuch as numerous reports of cystic kidneys without the presence of a cystic liver have been recorded. Luzzatto<sup>13</sup> in 90 cases of cystic disease of the kidneys found only five in which the liver was primarily involved. Moolten stated in his review that approximately 19 per cent of cystic kidneys had associated cystic livers.

Besides the kidney, cystic disease of the liver has, likewise, been associated with cystic disease of the pancreas, spleen, ovary and lungs.

The disease is frequently associated with other malformations wholly unrelated in type; for example, spina bifida, meningocele, polydactylism, vesical anomalies, *etc.*

The clinical picture of cystic disease of the liver presents no pathognomonic

features. McCaughan and Rassieur, in their review of 80 cases of non-parasitic cysts of the liver, found that very few were diagnosed preoperatively. Conditions most often confused with hepatic cysts are ovarian tumor, hydrops of the gallbladder, cystic kidney and, as occurred in our case, pancreatic cyst. It is probable that the majority of patients who have cystic disease of the liver never seek treatment for the condition, inasmuch as their liver function is very rarely impaired. Because of the association of cystic kidneys, and because the disease is usually more advanced in those organs, symptoms of urinary disturbances might be the presenting complaint. If, in such a patient, polycystic kidneys are discovered, only then can a similar process be suspected in the liver. On the other hand, if the cystic liver has enlarged to the point where it encroaches on neighboring structures, giving signs and symptoms referable to those structures, and if those structures have been proved to be without any organic pathologic lesion, then cystic disease of the liver may be included in the list of possibilities.

The most notable feature about our own case was the absence of any signs of malignant or systemic disease in spite of the upper gastro-intestinal symptoms and the presence of a large upper abdominal mass. There was very slight loss of weight, no loss of appetite, no change in the blood findings and no palpable lymphadenopathy.

If a cystic liver has enlarged to the point of causing a palpable mass, the identity of which cannot be proved, then exploration of the abdomen would be advisable. On encountering such a lesion, two alternatives are possible: Either (1) the involved portion can be removed; or (2) nothing should be done. The decision to excise the lesion must be made only after several factors have been considered. The kidneys should be palpated. If they, too, are involved seriously, then there is no point in attempting to excise a portion of the liver; the hazards of this procedure are well-recognized.

If the patient has been asymptomatic in spite of the presence of the cystic liver and if removal of the tumor would involve too great a risk, then one would be justified in doing nothing. If, on the other hand, the tumor is interfering with the patient's well-being, the kidneys are without palpable involvement and removal of the lesion would not be too hazardous a procedure, then extirpation certainly is justifiable.

In America, the first recorded resection of the liver, according to Keen,<sup>14</sup> was done by Tiffany in 1890. Keen himself, in 1892, resected a portion of the right lobe of the liver for a "cystic adenoma of the bile ducts weighing 113 Gm." Since then, resection of portions of the liver has been done a number of times. McCaughan and Rassieur, in reviewing 132 cases of non-parasitic cysts of the liver, found that excision of the involved portion had been performed in 29 cases, with a mortality rate of 17.2 per cent. Those authors make special note of von Haberer's<sup>15</sup> case, in which he resected the entire left lobe of the liver, "which was the site of a cyst the size of a child's head."

## SUMMARY

A case of cystic disease of the liver, in which the entire left lobe of the liver was removed surgically, is presented. The condition is discussed as to etiology, pathology, diagnosis and treatment.

As far as we were able to determine from the literature, this is the first reported case in which the entire left lobe of the liver was removed for cystic disease. The only other reported case of a similar nature was that of von Haberer, who, in 1908, removed the entire left lobe of the liver, wherein was a nonparasitic solitary cyst, which occupied the greater part of that lobe.

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# CONGENITAL CYSTIC DILATATION OF THE COMMON BILE DUCT

FOLLOW-UP ON PREVIOUSLY REPORTED CASE AND REPORT OF ADDITIONAL CASE

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SINCE congenital cystic dilatation of the common bile duct (choledochus cyst) if untreated eventually leads to death, whereas, surgical intervention offers cure or improvement, continued reports of this rare lesion are warranted in order to emphasize its existence, methods of early diagnosis, and proper treatment. For this reason two cases of our own are presented and discussed, one a previously reported case with follow-up study and the other recently observed. In addition the literature on this subject since our previous review<sup>1</sup> is brought to date.

**Case 1.**—P. W., a white male, age 20, was admitted to the Jefferson Medical College Hospital July 11, 1941, with the chief complaints of pain in the right upper abdomen, jaundice and fever, recurring at varying intervals over a period of eight months. A mass, six inches in diameter, was palpable in the right upper abdominal quadrant.

Laboratory studies revealed a moderate anemia (hemoglobin 65 per cent); grossly bile-stained urine; rapid sedimentation rate (31 mm. within one hour); low prothrombin time (38 per cent of average normal); impaired liver function (15 per cent bromsulfalein dye retention); hyperbilirubinemia (3.5 mg.); nonvisualization of the gallbladder by oral cholecystography; and displacement of the stomach, duodenum, jejunum and colon on roentgenologic examination of the gastro-intestinal tract with barium (Fig. 1, A and C). Peritoneoscopy revealed a large cystic retroperitoneal mass near the right kidney.

The patient was operated upon July 31, 1941, the preoperative diagnosis being retroperitoneal mass, probably choledochus cyst, with obstructive jaundice. A large choledochus cyst together with the gallbladder and cystic duct were excised *en masse*, and the right and left hepatic ducts implanted into the first portion of the duodenum over No. 18 F. catheters. Uneventful recovery ensued, and the patient was discharged on the 37th postoperative day. The catheters were removed through a gastroscope during a second hospital admission 11 weeks postoperatively.

Follow-up study, conducted over a period of three years and eight months, reveals that the patient's general health has remained excellent. He has been working steadily as operator of a metal planer for the past three years and has been happily married for two and one-half years. He is free of pain, jaundice, abdominal masses and fever, and has gained five pounds in weight. Bromsulfalein liver function study performed on March 13, 1945, revealed no dye retention, and the van den Bergh reaction was negative direct with serum bilirubin 1.0 mg. Gastro-intestinal series and barium enema study at this time revealed normal position of the stomach, small intestines and colon (Fig.

1, B and D). There was questionable regurgitation of a very slight amount of barium into the hepatic ducts.

**Case 2.**—E. K., a white female, age 58, was admitted to the service of Dr. Thomas A. Shallow at the Jefferson Medical College Hospital, July 13, 1944, with the chief complaint of abdominal swelling.

During the year prior to admission the patient noticed that her abdomen was gradually and persistently increasing in size. This enlargement was not associated with any discomfort or pain. Every three or four weeks she also noticed that her urine

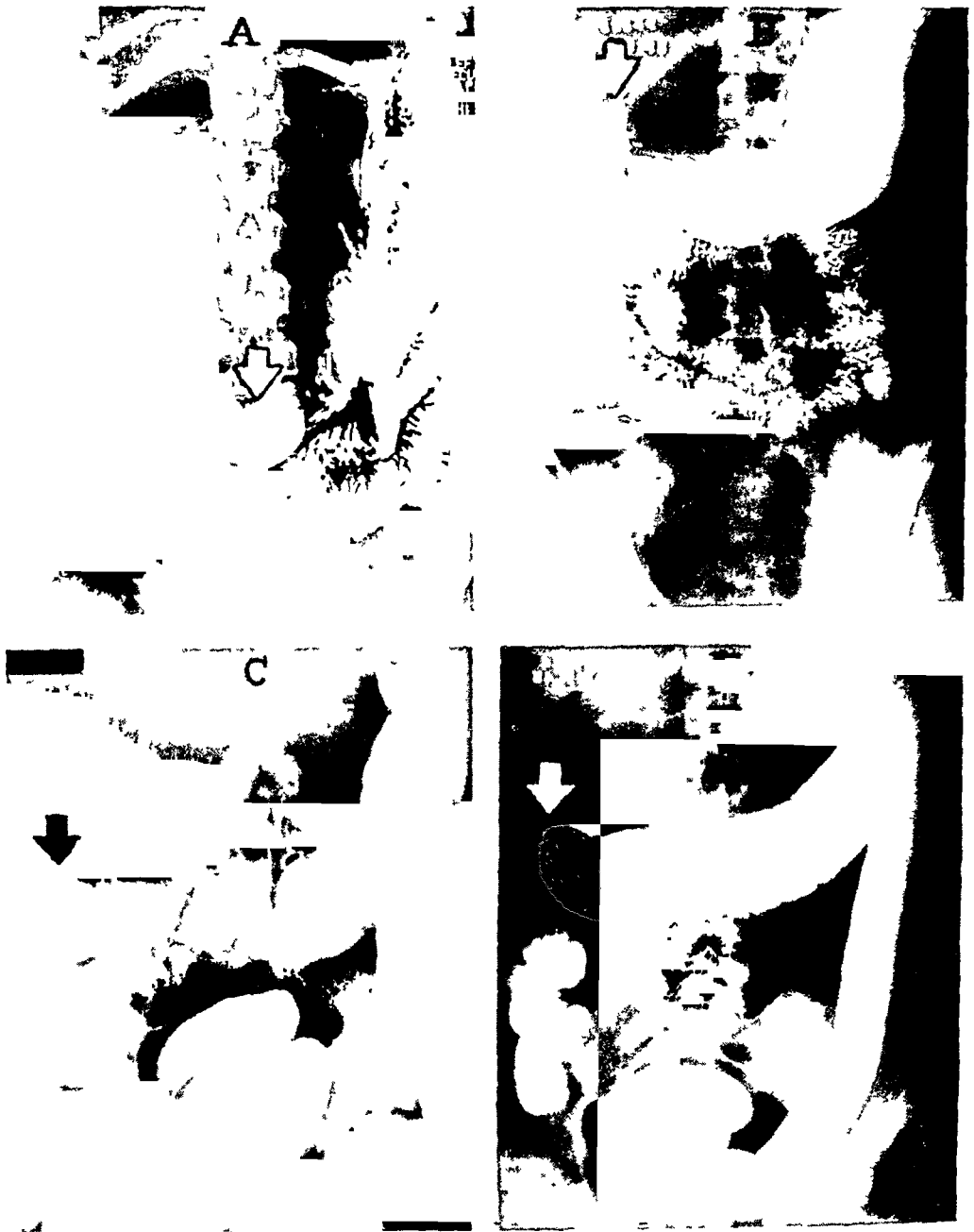


FIG. 1.—Roentgenologic studies in Case 1, in which the cyst was excised. Arrow in (A) shows displaced stomach and duodenum preoperatively, and in (B) the return to normal position postoperatively. Arrow in (C) shows displaced hepatic flexure of colon preoperatively, and in (D) the return to normal position postoperatively.

became darker than usual and her stools lighter in color for several days, but no jaundice was observed. There was no weight loss and her general health had remained excellent.

A review of the remaining systems disclosed a recent episode of senile vaginitis treated successfully by a gynecologist. The past history was otherwise uneventful for serious illnesses or operations. The family history failed to reveal any member ever having suffered from a similar ailment.

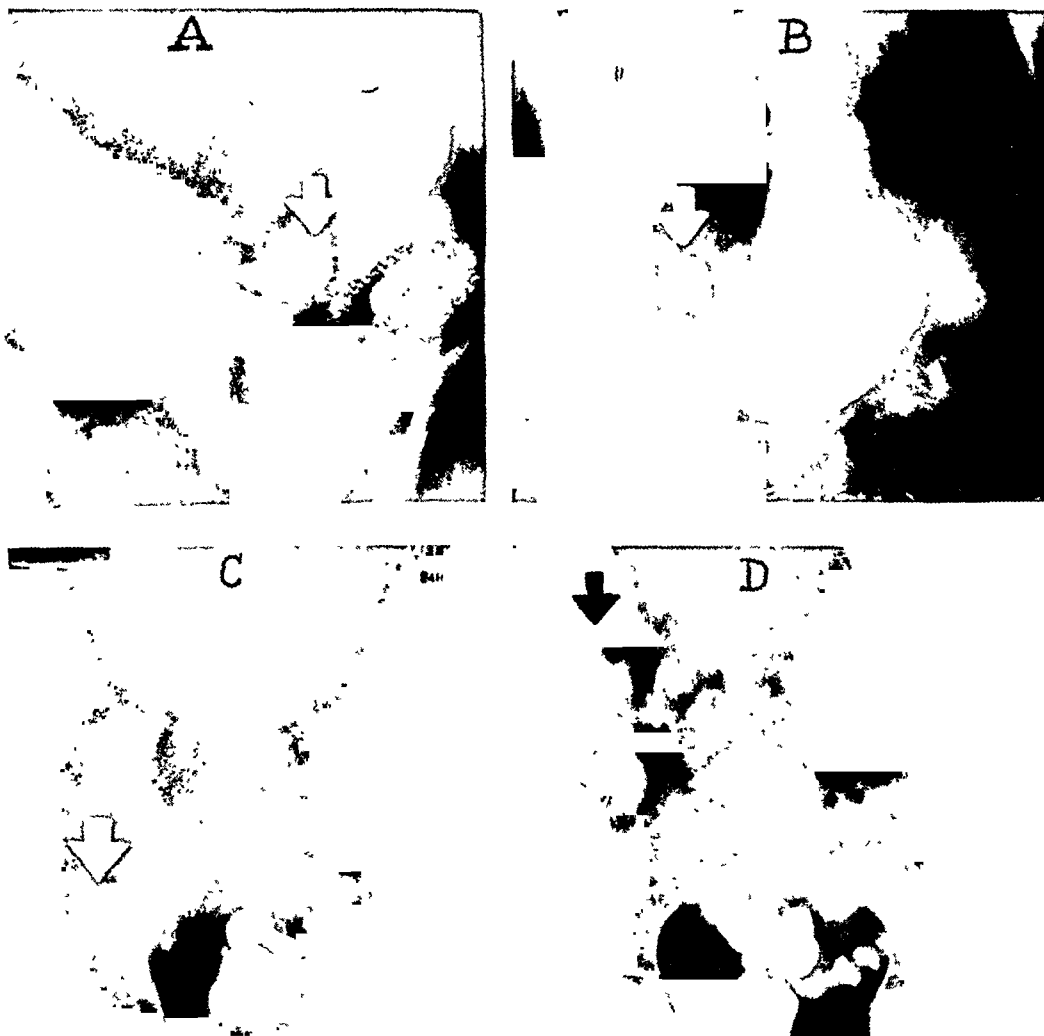


FIG. 2.—Roentgenologic studies in Case 2, in which the cyst was anastomosed to the duodenum. Arrow in (A) shows displaced stomach and duodenum preoperatively, and in (B) the return to normal position postoperatively. Arrow in (C) shows displaced hepatic flexure of colon preoperatively, and in (D) the return to normal position postoperatively.

*Physical Examination.*—The patient was a well-nourished middle-aged woman, who did not appear ill. The temperature, pulse, and respirations were normal. Blood pressure, 144/94. The scleras were moderately icteric and there was slight jaundice. Examination of the neck and chest was essentially normal. On inspection of the abdomen there was distention resembling that seen in the eighth month of pregnancy; the origin, however, appeared to be upper abdominal. The overlying superficial abdominal veins were slightly more prominent than usual. On palpation, a smooth, elastic, nontender, mobile mass was felt, which filled the entire upper abdomen, and extended to the level of Poupart's ligament on the right side and the lower costal margin on the left. This

mass moved slightly with respiration. Pelvic and rectal examinations as well as the extremities were normal.

*Laboratory Studies.*—Hemoglobin, 91 per cent; red cells, 4,700,000; white cells, 8,400, with polymorphonuclear cells 64 per cent, eosinophils 1 per cent, lymphocytes 32 per cent, and monocytes 3 per cent. Color index 0.96.

Routine uranalysis on four different days revealed very dark amber color; specific gravity ranging between 1.010 and 1.022; moderate albuminuria; no sugar; no acetone; and many white blood cells.

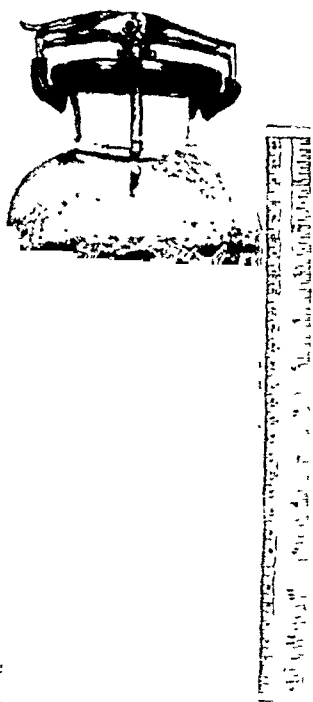


FIG. 3.—Appearance of cyst fluid in Case 2. The jar was filled one and one-half times (5,800 cc.).

Bromsulfalein liver function test showed 40 per cent dye retention. The van den Bergh reaction was positive direct with a serum bilirubin of 2.0 mg. The prothrombin time was 100 per cent of average normal.

Roentgenologic study of the gastro-intestinal tract with barium revealed that the stomach and duodenum were displaced markedly to the left and anteriorly by an enormous mass (Fig. 2A). The coils of small bowel were displaced downward and forward. The hepatic flexure of the colon was displaced downward to the level of the pelvic brim (Fig. 2C). There was no evidence of organic disease or obstruction in the gastro-intestinal tract.

The cholecystogram was indeterminate, but a questionable shadow which could have represented the gallbladder was noted anterior and lateral to the mass. No opaque or nonopaque calculi were noted.

*Preoperative Course.*—The patient was given a high carbohydrate, high protein, low fat diet supplemented by a pint of orange juice daily. In addition, 1,000 cc. of 10 per cent glucose in water with vitamin K mg. 3 were administered intravenously daily, and vitamin C mg. 50 and aminoids, one ounce, three times daily by mouth.

Following eight days of study and preparation she was operated upon with a preoperative diagnosis of choledochus cyst.

*Operation.*—July 20, 1944, Doctor Shallow: Under 20 mg. of pontocaine spinal anesthesia, an incision was made one inch below and parallel to the right costal margin, and the peritoneal cavity opened. A huge cyst which almost filled the entire abdomen was encountered. The duodenum was displaced medially and anteriorly, the transverse colon caudally, and the gallbladder laterally. The gallbladder was normal in size and contained no palpable stones. The liver, likewise, was of normal size and showed only slight cirrhotic change.

With a needle and syringe 10 cc. of thin dark brown fluid were withdrawn from the cyst which on culture yielded no bacterial growth in 48 hours. A suction trochar was then inserted and a gallon collecting jar was filled about one and one-half times (Fig. 3). Subsequent measurement of the fluid disclosed a total quantity of 5,800 cc., and chemical analysis revealed the presence of bile and a moderate amount of amylase.

Because of the age of the patient and the enormous size of the cyst, it was felt that extirpation carried an undue risk. Accordingly, anastomosis was performed between the most dependent portion of the deflated cyst and the first portion of the duodenum. While carrying out this procedure a biopsy specimen of the cyst wall was removed at the anastomosis site. A Penrose drain was inserted into the right kidney pouch and

brought out the lateral pole of the wound which was then closed in layers. The patient remained in good condition throughout the operation which lasted one hour and 15 minutes.

*Pathologic Examination of Biopsy Specimen of Cyst Wall.*—The cyst wall consisted of fibrous tissue, 5 mm. thick, in which there were areas of recent hemorrhage. An epithelial lining was lacking (Fig. 4).

*Postoperative Course.*—The immediate response and convalescence were essentially uneventful. Wangensteen suction was instituted for the first three days, during which time the patient received glucose in saline intravenously, supplemented with vitamins C and K and amino-acids. She received 500 cc. of blood shortly after operation and also on the 10th and 18th days postoperatively. The drain was withdrawn during the seventh and eighth days. The wound healed without infection, and the patient was

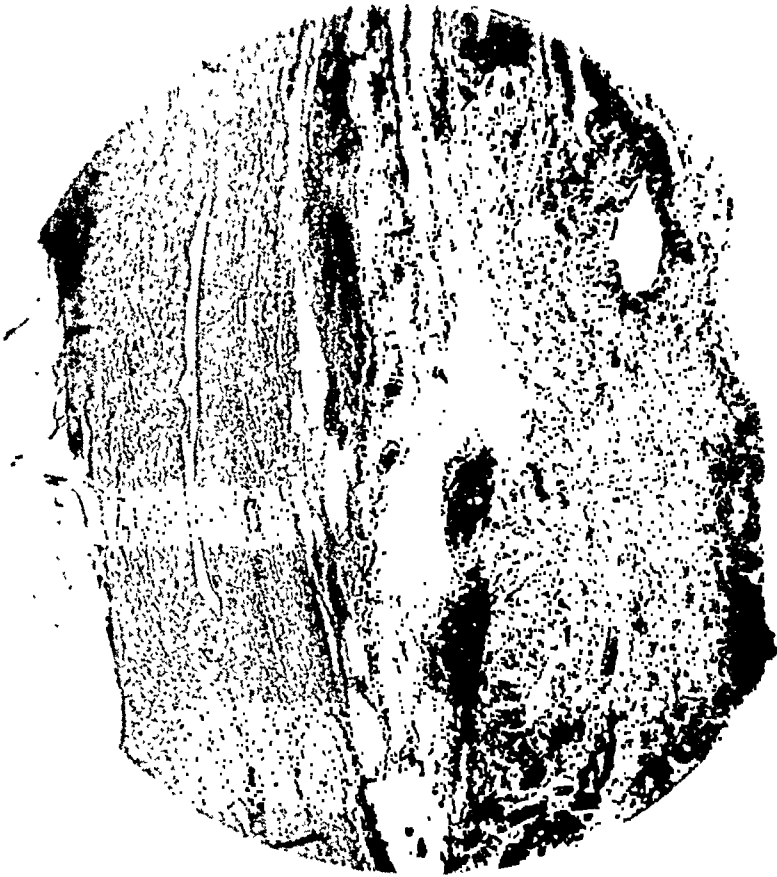


FIG. 4.—Photomicrograph of wall of cyst in Case 2. ( $\times 37.5$ )

discharged on August 17, 1944, the 28th day postoperatively. At this time there was no evidence of abdominal enlargement and the serum bilirubin was 0.5 mg.

*Subsequent Course.*—Follow-up study February 15, 1945, approximately seven months postoperatively, revealed that the patient was entirely well, had a good appetite, and was free of abdominal swelling, jaundice or pain. The wound remained well healed. Roentgenologic study of the gastro-intestinal tract with barium showed the stomach, small intestine and colon in a normal position (Fig. 2 B and D). Cholecystogram failed to reveal a gallbladder shadow and there was no evidence of opaque calculi. Liver function study, March 21, 1945, eight months postoperatively, revealed 5 per cent retention of the bromsulfalein dye. At this time the van den Bergh reaction was negative direct and serum bilirubin 0.7 mg.



DISCUSSION.—Since our previous review of the literature<sup>1</sup> there have appeared case reports by Smith<sup>2</sup> (two cases), Gray,<sup>3</sup> Swartley,<sup>4</sup> Nitsche,<sup>5</sup> and Hutchins and Mansdorfer.<sup>6</sup> These, in addition to our own new case, bring the total authentic cases to 182. The report of Diebold<sup>7</sup> is not available at present and for that reason is not included. The addition of these few reports adds little of significance to our recent analysis of 175 cases, and, therefore, a further analysis is not warranted at this time.

If the lesion is not suspected preoperatively it is important to recognize it promptly at celiotomy in order to avoid unduly long exploration and improper treatment. The frequent but not constant triad of symptoms and signs, namely, tumor (77 per cent), jaundice (70 per cent) and pain (59 per cent), should suggest the correct diagnosis if the lesion is kept in mind as a diagnostic possibility. Tumor and jaundice, which are the most constant features of the triad, were present in both of the authors' cases, but pain was absent in Case 2. The statement frequently seen in the literature that no relation exists between the size of the cyst and the severity of the pain is well borne out in this case. The importance of preoperative diagnosis is demonstrated by the fact that in 22 cases in which it was correct, or suspected, the mortality was 36 per cent, whereas, in 153 cases in which the diagnosis was incorrect, or none made, the mortality was 62 per cent. In each of our two cases the outcome was favorably influenced by the preoperative suspicion of the lesion, improvement of the patient's condition prior to operation and properly selected surgical treatment.

Anastomosis of the biliary and intestinal tracts is essential to prevent biliary cirrhosis, cholangitis, liver abscess, hemorrhage, or rupture of the cyst. The cyst itself may be anastomosed, as first advocated by Bakes,<sup>8</sup> in 1907, or excised and the remaining choledochus, common hepatic duct or both hepatic ducts joined to the intestine; or the gallbladder may be anastomosed when a free communication exists between this organ and the cyst. Primary performance of this group of procedures carried a mortality of 27 per cent in 60 cases, whereas, external drainage of the biliary system followed by secondary anastomosis to the gastro-intestinal tract carried a mortality of 29 per cent in 24 cases. The latter procedure entails a slightly higher mortality because of the formation of an external biliary fistula, hemorrhagic tendency due to low prothrombin values, and the extra burden of two operations. It should be performed only in cases in which the operative risk is very great, as by marked debilitation or severe infection.

Although primary anastomosis of the biliary and intestinal tracts has been established as the procedure of choice, it is debatable whether or not the cyst should be excised. Extirpation of the cyst with primary anastomosis of the remaining duct system to the duodenum seems more physiologic, since it creates a more normal union between the liver and duodenum and eliminates the cyst which may harbor infection. This method, however, carries a higher mortality (three deaths in seven reported cases) and should only be considered when the patient is a good operative risk, the cyst large, and infection

minimal or absent. The number of reported cases in which this procedure has been carried out is too few (follow-up reports even fewer) to warrant any conclusions as to the value of the general employment of the method. The authors' Case 1, nevertheless, demonstrates the feasibility of the procedure in a properly selected patient. Anastomosis of the cyst, as in the authors' Case 2, gives satisfactory results, particularly in surgically handicapped patients and is the procedure recommended in the ordinary case. The remaining dilated duct may harbor regurgitated food, however, leading to severe ascending cholangitis (case of Fowler<sup>9</sup>).

The amount of cyst fluid usually varies from 30 cc. to several liters. The aspiration of 5,800 cc. in the authors' Case 2 is most unusual. In the case of Reel and Burrell,<sup>10</sup> disputed by Poate and Wade<sup>11</sup> as not being authentic and not included in our previous review, 8,000 cc. are reported. Other authors recording large amounts of cyst fluid are Smith<sup>2</sup> (Case 1, 5,200 cc.), Yotuyanagi<sup>12</sup> (Case 2, 5,200 cc.), and Fukada<sup>13</sup> (Case 1, 5,000 cc.).

Little is known about the late results in cases of recovery following operation, as seldom is anything further reported concerning the progress of the patient. McConnell,<sup>14</sup> Berkley,<sup>15</sup> and Gross<sup>16</sup> each reported cases in which the patients were well after four years. Cases reported as well for more than five years are those of Iselin,<sup>17</sup> Hildebrand,<sup>18</sup> McWhorter,<sup>19</sup> Murata,<sup>20</sup> Walton,<sup>21</sup> (second case), Wheeler,<sup>22</sup> Sumpter,<sup>23</sup> and Judd and Greene.<sup>24</sup> 2 Swartley and Weeder's<sup>25</sup> 4 case died ten years later of hemorrhage from esophageal varices due to portal obstruction. The case of McWhorter<sup>19</sup> died 13 years later of uremia with nephrosclerosis, hypertension, and diabetes. Judd and Greene's<sup>24</sup> case in a 13-year follow-up is reported by Smith<sup>2</sup> to have symptoms similar to gallbladder disease. The case of Wheeler<sup>22</sup> died 15 years later at the age of 80.

#### SUMMARY AND CONCLUSIONS

1. Despite the rarity of congenital cystic dilatation of the common bile duct, 182 authentic cases in the world literature, we have personally encountered two cases herein reported.

2. The lesion was suspected preoperatively in both instances. The diagnostic triad—tumor, jaundice, and pain was present in one case, but pain was absent in the other.

3. In Case 2, 5,800 cc. of cyst fluid represent the largest amount recorded in an undisputed case.

4. The safest treatment, and the one recommended for general employment, is primary anastomosis of the cyst to the duodenum. This procedure was successfully performed in Case 2.

5. Extirpation of the cyst followed by primary anastomosis of the remainder of the biliary duct system to the duodenum may be attempted if the lesion is suspected preoperatively, the patient a good operative risk, the cyst large, and infection minimal or absent. The feasibility of this procedure is

demonstrated in Case 1, in which the patient is entirely well three years and eight months postoperatively.

6. A contribution of follow-up studies is needed from authors who report cases of operative recovery, in order to accumulate more conclusive data as to the value of the various surgical procedures and their ultimate prognosis.

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# TRAUMATIC RUPTURE OF THE GALLBLADDER

## CASE REPORTS

## AND

## NOTES ON CHOLEPERITONEUM

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SPONTANEOUS PERFORATION of diseased gallbladders is not unusual. Traumatic rupture of normal gallbladders is rare. There is confusion in the literature about the number of traumatic cases reported. Cole,<sup>1</sup> in reporting an instance in 1935, declared that his was the fourth to be presented, whereas Vance,<sup>2</sup> in 1928, stated that Lewerenz,<sup>3</sup> in 1903, recorded 23 instances. In reviewing the literature on this subject, it is evident that several reports on traumatic rupture of the gallbladder lack proof that such a condition existed. Many were recorded in which aspiration of bile-stained fluid was the only evidence upon which the diagnosis was made. Neither operation nor postmortem examination was done. It became apparent that some instances of diseased gallbladder which had ruptured in connection with a vague and inconclusive history of injury were reported as traumatic ruptures. There were also duplications of cases recorded by two or more authors.

When bile is found intraperitoneally following a blow to the abdomen, the most likely source is laceration or tear of the liver. This is due to the size and relative fixation of this organ. Rupture of the bile ducts is next to be thought of because they also are fixed and susceptible to tearing. The ducts are short and well-protected, so that subcutaneous traumatic injury to these structures is rare. The gallbladder is the least likely to be the source of choleperitoneum because this viscus is well-protected under the liver and is mobile. It is only when the gallbladder is distended with bile that it is likely to perforate when a blow is received in this region. The bile cannot escape through the cystic duct and the hydrostatic pressure within the gallbladder becomes greater than the tensile strength of its wall; hence, the "balloon bursts."

In this presentation no instance is included unless there is definite proof of subcutaneous traumatic rupture of the gallbladder, either by operation or postmortem examination. Patients are prone to attribute the development of symptoms to something that happened to them. This is particularly true of abdominal complaints. In most instances the food or drink or alleged trauma has nothing to do with the development of the condition. It has, therefore, been necessary to exclude almost all of the reports where the gallbladder or biliary passages were diseased as evidenced by the presence of stones and pathologic change in the gallbladder wall. War wounds, stab wounds, and gunshot wounds are not included in this review.

Lewerenz,<sup>3</sup> in 1903-1904, reported on 63 cases of subcutaneous traumatic rupture of the gallbladder, liver, and biliary passages gathered from the literature, including one instance of his own. In 1905, Ricketts<sup>4</sup> presented an historical review including both traumatic and spontaneous ruptures. From these two reports the subcutaneous traumatic ruptures of the gallbladders have been taken. No attempt has been made to check their sources. Both authors give fairly complete accounts of each patient, so that it has been possible to segregate the traumatic from the spontaneous ruptures. There are also duplications of reports by the two writers, and these have been checked. Reports occurring in the literature since 1905 have been taken from the original articles.

#### CASES CITED

1. Robson, Mayo, 1388.<sup>4</sup> The author reports on a specimen in Guy's Museum, the case of a lacerated gallbladder of a male, age 29, who was kicked in the abdomen, and died on the 178th day following injury.
2. Stuart, 1734.<sup>4</sup> A male patient, with traumatic rupture of the gallbladder died on the seventh day. Autopsy showed rupture of the fundus of the gallbladder.
3. Alberti, 1747.<sup>3</sup> A male was kicked in the abdomen and died after a few hours. Autopsy: Rupture of the gallbladder. The torn place was in the wall adjacent to the liver.
4. Skeete, 1785.<sup>4</sup> A boy, age 14, had traumatic rupture of the gallbladder. He survived for five weeks. Paracentesis was done, and postmortem examination revealed perforation of the gallbladder.
5. Operator Unknown, 1796.<sup>4</sup> A male patient, with traumatic rupture of the gallbladder died on the third day. Postmortem examination revealed perforation in the fundus of the gallbladder.
6. Blumenthal, 1847.<sup>3</sup> A boy, age 15, fell on his abdomen. There was pain in the region of the liver, icterus, and collection of bile-stained fluid in the abdomen. The patient died after several days. Autopsy: Rupture of the neck of the gallbladder near the cystic duct. The liver was normal. More than a "bucketful" of biliary fluid was found in the abdominal cavity. The peritoneum was thickened.
7. Fergus, Walter, 1848.<sup>4</sup> Author reports a patient, age 17, with traumatic rupture of the gallbladder. Autopsy revealed the condition.
8. Folsom, 1869.<sup>3</sup> A boy, age 12, was kicked in the right side of the abdomen. There was violent abdominal pain. On the following day he had persistent diarrhea. Despite the injury the boy went to school and took part in physical exercises. On the tenth day he became suddenly worse, with vomiting, cramps, and death. Autopsy: Rupture of the gallbladder, with bile in the abdominal cavity. There was also fibrinous peritonitis.
9. Janeway, 1874.<sup>3</sup> There was rupture of the gallbladder after a fall. The patient died. Autopsy: Rupture of the gallbladder, with old adhesions which might have made the patient more vulnerable to injury of this organ. There was marked retroperitoneal exudation of bile.
10. Martel, 1882.<sup>4</sup> A male, age 33, had traumatic rupture of the gallbladder, with peritonitis. He died two weeks after the injury. Autopsy revealed the condition.
11. Dixon, 1887.<sup>3</sup> A male, age 32, fell from a considerable height. Besides minor wounds he showed evidence of peritoneal irritation, swelling of the abdomen with fluid, and icterus. Paracentesis in the ileocecal region yielded bile. Cholecystectomy was performed eight days after the injury because of a large tear in the gallbladder. After the operation icterus became more marked. The patient died 17 days after operation of cholemia. Autopsy: In the common bile duct there were two concretions which

caused obstruction and which were probably carried there by the trauma. Bile had infiltrated along the posterior margin of the ascending colon retroperitoneally. (Note: It is questionable whether this case should be included in this series. The author does not state clearly that these concretions were gallstones, blood clots, or something else.)

12. Moyer, P., 1891.<sup>4</sup> A male, age 13, had traumatic rupture of the gallbladder, with peritonitis. Death occurred two weeks later. Autopsy revealed the condition.

13. Schopf, 1894.<sup>4</sup> Author reports a male, age 60, with traumatic rupture of the gallbladder. He was operated upon, but died.

14. Walton, 1897.<sup>4</sup> A small wound in the fundus of the gallbladder was sutured but the patient died of peritonitis. At autopsy the wound proved to be closed.

15. Bullinger, 1898.<sup>4</sup> A female, age 23, had traumatic rupture of the gallbladder. Celiotomy was performed, the gallbladder was sutured, and the patient recovered.

16. Munn, Wm. P., 1898.<sup>4</sup> A male, age 25, at operation, had three pints of bile removed from the abdomen. The gallbladder was sutured, but he died 36 hours after the operation.

17. Thomas, 1898.<sup>3</sup> A boy, age 14, fell a considerable distance, striking the abdomen. He collapsed, and later complained of pain in the abdomen. There was evidence of peritoneal irritation. Celiotomy was performed the following day. A large amount of bile was found in the abdominal cavity. The gallbladder was completely torn off, so that it could not be sutured. The patient recovered.

18. Caselli, 1898.<sup>3</sup> The author describes a case of rupture of the gallbladder which was operated upon and sutured, with recovery. Leverenz records this case in an appendix to his main article and states that it was taken from an anniversary publication for Durante.

19. Czerny, 1899.<sup>3</sup> A boy was run over by a heavy wagon. Despite abdominal pain he was able to walk. There was evidence of fluid in the abdomen and slight icterus. The stool was acholic. Paracentesis four weeks after injury was done, and 4.5 liters of bile-stained fluid were obtained. Celiotomy was performed five weeks after injury, at which time 5.5 liters of bile-stained fluid was removed from the abdomen, and two tears in the gallbladder were sutured. The patient recovered.

20. Cholzow, 1900.<sup>3</sup> A male, age 20, was kicked in the region of the liver. He developed jaundice, and there was evidence of fluid in the abdomen. Three paracenteses were done and each time 5.5 to 6 liters of bile-stained fluid were obtained. Celiotomy was performed 43 days after the accident, at which time a large rupture in the gallbladder was found. Cholecystectomy resulted in recovery.

21. Robson, Mayo, 1901.<sup>4</sup> The patient died as a result of a fall. Postmortem examination showed the fundus of the gallbladder to be perforated.

22. Edwards, S., 1903.<sup>4</sup> The author reports traumatic rupture of the gallbladder in a boy, age seven. The gallbladder was sutured and the patient recovered.

23. Siegel, 1909.<sup>5</sup> Mentioned by J. A. Hicks,<sup>6</sup> in which rupture occurred eight days after the injury. It was thought to be due to extension of gangrene secondary to trauma.

24. Fortier, L. A., 1914-1915.<sup>7</sup> Author reports a white female, age 11, who was injured 12 days before admission to the hospital. At celiotomy, rupture in the gallbladder was found. The perforation was sutured and a catheter was placed in the gallbladder, and brought out through the abdominal wall. The patient recovered.

25. Fifield, Lionel R., 1926.<sup>8</sup> Records a male, age 22, who was run over by a cart. Two months later he reported to the doctor because of increase in the size of the abdomen. Celiotomy was performed. A large amount of bile was found in the peritoneal cavity and perforation of the gallbladder, which was sutured. The patient recovered.

26. Robertson, Hugh, 1931.<sup>9</sup> This is the report of a male, age 11, with ruptured gallbladder hanging by a few threads to an uninjured liver. There was extensive bile peritonitis. The gallbladder was removed and the wound was drained. The patient made a slow recovery.

27. Brown, Henry P., Jr., 1932.<sup>10</sup> This is an instance of a male, age 18, who had been in an automobile accident. There was complete avulsion of the gallbladder, the organ floating free in a pool of blood in the abdominal cavity. Operation was performed 13 hours after the injury, and the patient recovered.

28. Cole, A. V., 1935.<sup>1</sup> A white male, age 50, sustained an upper abdominal injury. Operation was performed two hours afterwards. The gallbladder was perforated. Cholecystectomy resulted in recovery.

29. Roberts, M. A. W., 1937.<sup>11</sup> The author reports a patient who had traumatic perforation of the gallbladder together with injury to the left foot, so that an immediate amputation had to be performed. Although there was one small stone in the gallbladder, the author is convinced that it had nothing to do with the rupture. The patient died, and postmortem examination revealed fat necrosis, although no injury to the pancreas could be demonstrated. The stomach contained blood which came from vessels in the duodenum. (Note: Undoubtedly there had been sufficient injury to the pancreas to permit escape of pancreatic juice. Bile alone does not produce fat necrosis.)

30. Hicks, J. A., 1944.<sup>6</sup> This report concerns the case of a boy, age three, who fell on the abdomen, and was found, on exploration, to have a perforation in the fundus of the gallbladder. The patient recovered.

31. Sengstacken, Royal F., 1944.<sup>12</sup> A male, age 28, was struck in the upper part of the abdomen by the steering wheel of an automobile. At operation, a rent in the fundus of the gallbladder was found. The tear was sutured, the abdomen was drained, and the patient recovered.

32. **AUTHOR'S CASE REPORT.**—A male, white, age 37, was admitted to the King County Hospital at 2:31 A.M., November 22, 1942, following an automobile accident. Examination by the intern at that time revealed evidence of moderate imbibition of beer. He complained of pain in the left leg. Roentgenologic examination showed fracture of the left fibula, without displacement. In the afternoon he complained of epigastric pain, especially on the right side. It was then learned that he had been treated for ulcer about two years previously, although no roentgenologic examination had been done at that time. When I saw him there was considerable pain and rigidity, especially in the right upper quadrant extending downward. Peristaltic sounds were almost absent.

Roentgenologic examination revealed no evidence of air in the peritoneal cavity. The temperature was normal; the pulse 100; blood count and uranalysis were within normal limits.

**Operation.**—Celiotomy was performed at 8:00 P.M., with preoperative diagnosis of perforated duodenal ulcer. Upon opening the abdomen, however, bile was found in the right gutter extending down to the pelvis. Examination of the gallbladder revealed a rent, about 1.5 cm. in extent, in Hartman's pouch. There was no evidence of injury to the liver, bile ducts, intestines, stomach, pancreas, or any other organ within the abdominal cavity, nor was there evidence of injury to the abdominal wall. No duodenal or gastric ulcer could be demonstrated. The gallbladder appeared normal and contained no stones.

**Operative Procedure.**—Through an upper right paramedian incision the gallbladder was brought up; the rent in the wall of it was sutured with fine silk; an incision was made in the fundus of the gallbladder and a moderate-sized rubber tube was inserted into the lumen. A purse-string of chromic No. 00 was placed around it and the tube was brought out through a stab wound to the right of the main incision. Most of the bile in the peritoneal cavity was removed by suction. The abdomen was closed.

Postoperative convalescence was uneventful. The patient was moved to the United States Marine Hospital in Seattle on the sixth postoperative day, where he remained for one week. On the tenth postoperative day the cholecystostomy tube was removed. A small amount of bile drained for a day or so after its removal, and the wound healed without evidence of infection. The patient reported to the office for a check-up examination three weeks after operation. In one month he returned to his usual occupation of

fisherman. He was last seen in January, 1945, at which time he stated that he had been in good health and had had no symptoms attributable to the injury.

#### NOTES ON CHOLEPERITONEUM

In reviewing the literature on traumatic rupture of the gallbladder one is impressed with the treatment of choleperitoneum before the turn of the century. At that time, aspiration of bile or bile-stained fluid was recorded in almost every instance. It seems that the authors were especially concerned with reporting the large amounts of fluid aspirated. This led Lewerenz<sup>3</sup> to the correct conclusion that it is not sufficient to aspirate bile but that operative procedure designed to close the wounds from which bile escapes is necessary. He pointed out that repeated aspiration is not only futile but dangerous, and records two instances in which patients died from perforation of the bowel due to aspiration. The mortality was very high with aspiration.

Considerable work has been done to determine the toxicity of bile in the peritoneal cavity. At present, there is no unanimity of opinion on this subject. A few authors believe that bile in the abdomen is harmless.<sup>13, 14</sup> Of those who state that choleperitoneum is harmful, there are three opinions as to the manner in which it produces toxic symptoms. One group of investigators has concluded that bile causes death due to the toxicity of its components, especially bile salts and bile acids.<sup>15-18</sup> Another is of the opinion that bile is fatal only if it becomes infected, especially with *Clostridium welchii* or a similar organism.<sup>19-23</sup> A third group states that choleperitoneum produces shock by fluid loss from the circulation into the peritoneal cavity.<sup>15-20-21</sup>

Much experimental work has been done, especially on dogs and guinea-pigs. It was found that dog bile is toxic to the animals and, when present in sufficient quantities within the abdomen, causes death within 24 hours.<sup>10</sup> Since dog bile contains a high percentage of taurocholic acid it is much more toxic than human bile, which contains mostly glycocholic acid. Confusion arose over the fact that frequently large amounts of bile-stained fluid was removed and called "pure bile."<sup>16</sup> It is now evident that a few cubic centimeters of bile can stain several hundred cubic centimeters of fluid, so that it looks like bile. In none of the reports where large amounts of bile-stained fluid were removed from the abdomen was the bile salt content determined.<sup>16</sup> It is well-established that choleperitoneum sets up severe reactions, causing adhesions between loops of bowel and other structures, and tends to dilute itself markedly by forming a transudate. Cyst-like cavities are formed and these at times reach huge proportions. If the bile that is present in these localized collections of fluid is small in amount there is little systemic reaction. When bile is allowed to spread throughout the abdomen, toxic symptoms develop and death may supervene in a few hours. Unless the condition is relieved, the lymphatics of the peritoneum become obstructed and ascites develops.

This has been recorded by Vance,<sup>2</sup> who had a patient that died on the 15th



day following laceration of the liver. At first he had pain; then he became markedly jaundiced; icterus gradually disappeared but distention of the abdomen developed. Aspiration revealed bile-stained fluid. Postmortem examination revealed the abdomen distended with bile. A thick coat of brownish material was found over every part of the peritoneal surface. Vance interprets the chain of events as follows: At first, much bile was excreted through a laceration on the under surface of the liver. Most of this bile was absorbed and jaundice was produced. Later, the bile caused a nonseptic peritonitis from chemical irritation, with formation of enormous fibrinous exudate which blocked the pathway of absorption from the serous surfaces. This condition resulted in accumulation of bile in the abdominal cavity and the disappearance of bile elsewhere. Maingot<sup>22</sup> reports an instance with similar findings.

Horral<sup>16</sup> carried out extensive experiments on dogs and found that when bile was spilled into the peritoneal cavity the animals became ill but survived. If an intraperitoneal fistula of the gallbladder was made so that bile was spilling into the peritoneal cavity continuously, all of the dogs died within 24 hours. Intraperitoneal injection of bile in the amount of 5 cc. per kilogram of weight also caused death in 24 hours. In a few instances bacterial growth was obtained from bile of dogs used for injections. Bacteria were also found in the peritoneal fluid in the dogs who died when bile had been injected. These organisms were staphylococci and colon bacilli. Horral feels that bacteria would not have had time to cause death, as these dogs died within 24 hours. *When sterilized bile was injected intraperitoneally in the amounts of 5 cc. per kilogram of body weight, death, also, occurred within 24 hours, although the cultures were negative.*

Manson and Eginton,<sup>15</sup> in 1938, working with dogs and guinea-pigs, injected human bile, dog bile, ox bile, and *Clostridium welchii* intraperitoneally. They came to the following conclusion: "It is thus seen that bile possesses some specific toxic or devitalizing action, apparently not dependent upon contained *Cl. welchii* or anaerobes liberated upon escape of bile into the peritoneal cavity. This specific toxic action is quantitative and appears to be due to the bile salt content of the bile." They also conducted experiments on bile in the peritoneal cavity producing shock and arrived at this decision: "This experiment seems to confirm the contention that shock due to fluid loss from the circulatory channels must be a factor in the causation of death in bile peritonitis, and it also indicates the therapeutic value of intravenous isotonic colloid solution in the treatment of this condition in dogs." They decided that there are at least two factors causing death in choleperitoneum, and that the primary factor is the toxic effect of bile salts; the secondary factor is the loss of fluid from the vascular system.

There are clinical reports which indicate that bile, as such, is toxic in the human. McLaughlin<sup>23</sup> reports eight instances, three of which were operated upon with recovery. Four died from bile peritonitis in *from 14 to 48 hours after onset of choleperitoneum*. One died without benefit of surgery, having

been admitted to the hospital *in extremis*. He states that the mortality rate is from 50 to 75 per cent.

Douglas and Turner<sup>24</sup> record a patient who died in about 30 hours following operation for common duct stones. Death was due to bile peritonitis, as proved by autopsy. These authors also cite an instance where a patient died 24 hours following the premature removal of a drain. Postmortem examination revealed death to be due to bile peritonitis.

The writer had a patient who had spontaneous perforation of the gallbladder, but who refused operation. She died within 48 hours. Postmortem examination disclosed choleperitoneum. There was no evidence of infection.

In summing up the evidence regarding toxicity of bile in the peritoneal cavity, it seems that most of the careful experimental work points to the conclusion that bile is toxic and is the prime factor in the cause of death; that shock supervenes and plays a secondary but important rôle; and that infection is the least important, but may be a factor if death occurs late. Bile in the abdominal cavity, if present in small amounts, can be tolerated for months, provided it is walled-off. Generalized choleperitoneum is fatal within a short time.

#### SUMMARY

1. Thirty-one authentic instances of subcutaneous traumatic perforation of the gallbladder have been found in the literature. One additional case is reported, making a total of 32.

2. It is believed that Horrall's<sup>16</sup> conclusion is essentially correct, namely: "Bile peritonitis is caused by the toxic action of bile acids. Bile acids exert a toxic effect on the heart, kidneys, blood, and blood capillaries and on all tissue with which they come in contact. Bacteria have little or no effect if the peritonitis is fatal within a few hours. Secondary surgical shock is a very important result of the toxic action of bile acids."

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## SARCOMA COMPLICATING PAGET'S DISEASE OF BONE\*

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THE YEAR 1952 will mark a century since Sir James Paget observed his first patient with an unknown disease which he later described and named osteitis deformans. From 1852 to this patient's death in 1867, Paget closely watched the enlargement of the head, the bowing of the bones, and the decrease in height typical of this condition. In 1876, he delivered an address before the Royal Society of London, giving his classical description of osteitis deformans with a report of five such cases. In 1882, he reported seven additional cases.<sup>44</sup>

The description of this "spongy hypertrophy of bone,"<sup>26</sup> as given by Paget in 1876, has been unsurpassed, and very little has been added since his time: "It begins in middle age, or later; is very slow in progress; may continue for many years without influence on the general health; and may give no other trouble than those which are due to the change of shape, size, and direction of the diseased bones. Even when the skull is hugely thickened, and all its bones exceedingly altered in structure, the mind remains unaffected."

"The disease affects most frequently the long bones of the lower extremities and the skull, and is usually symmetrical. The bones enlarge and soften, and those bearing weight yield and become unnaturally curved and misshapen. The spine, whether by yielding to the weight of the overgrown skull, or by change in its own structure, may sink and seem to shorten with greatly increased dorsal and lumbar curves; the pelvis may become wide; the necks of the femora may become nearly horizontal; but the limbs, however misshapen, remain strong and fit to support the trunk. In its earlier periods, and sometimes through all its courses, the disease is attended with pains in the affected bones; pains widely various in severity and variously described as rheumatic, gouty, or neuralgic, not especially nocturnal or periodical. It is not attended with fever."<sup>43</sup> Virchow suggested the name *leontiasis ossea* for those cases in which the facial bones and skull only are thickened while the other bones escape.<sup>43</sup>

In the early stages of Paget's disease the involved bones are soft and easily cut with a knife. It is during this time that the weight of the body causes bowing of the long bones. Later the bone becomes hard and further thickened. Microscopically, there is first a replacement of the original bone by connective tissue, and then a substitution of finely porous cancellous bone which gradually becomes harder. Absorption and ossification go on together, but the latter outstrips the former so that the bone becomes thick, though still finely porous. One of the most characteristic features of the

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\* Read before the Philadelphia Academy of Surgery, April 2, 1945.

microscopic picture is the great number and irregular arrangements of the lamellar systems, which is seen in no other disease of bone. This gives what is known as a mosaic structure due to variously-shaped areas of new and old bone separated by ground substance. The medullary cavity is filled with fibrous tissue.<sup>5</sup>

#### NATURE AND ETIOLOGY OF PAGET'S DISEASE

The nature of this condition is still unknown. Paget considered it to be an inflammatory process, hence he suggested the name "osteitis deformans."<sup>43</sup> Looser, von Albertini, Freund, Erdheim, Haselhofer, and others, also thought it most likely a chronic inflammation. They ascribed the frequent development of bone sarcomas to this prolonged chronic inflammation.<sup>52</sup> Endocrine disorders have been strongly suspected as the etiologic basis, and the most popular theory at the present time is that of parathyroid dysfunction. Since osteitis deformans is somewhat similar macroscopically and microscopically to osteitis fibrosa cystica, it seems reasonable to suspect a related etiologic factor. The blood plasma alkaline phosphatase is greatly increased in osteitis deformans—even more than in osteitis fibrosa cystica. However, there are no symptoms of hyperparathyroidism and no demonstrable parathyroid hyperplasia in Paget's disease, and the blood calcium and phosphorus show normal values.<sup>5</sup> In the two cases reported by Davie and Cooke,<sup>14</sup> there was microscopic evidence of reduction in the oxyphil cell content of the parathyroids. At the age when Paget's disease, and especially when Paget's sarcoma, is most common, the oxyphil cell content is normally high. They considered this significant because, according to some endocrinologists, these cells may be concerned with elaboration of a growth-retarding hormone. Moehlig and Adler<sup>38</sup> believe the pituitary gland is involved primarily and that the parathyroids are affected secondarily.

Some attention has been focused on the thyroid gland as a possible etiologic factor. In several uncomplicated cases of Paget's disease and also Paget's sarcoma, the thyroid gland is reported to have shown an increased fibrosis and decreased glandular tissue element, while several others showed an hyperplasia of the glandular tissue.<sup>14</sup> The adrenals have been mentioned. Other theories of etiology include syphilis, hereditary factors, neuropathies, trauma, bacterial infections, and arteriosclerosis.<sup>52</sup>

#### FREQUENCY OF PAGET'S DISEASE

Although hospital records are the most accurate source at the present time, they do not give a true picture as to the frequency of Paget's disease in the general population. Many uncomplicated cases of osteitis deformans never come to the hospital, and in some of the others the diagnosis has been overlooked; also, some complicated cases have been indexed in the hospital records under the complication rather than under Paget's disease itself. In 1927, Bird,<sup>3</sup> on examining the records of four large Boston hospitals, found Paget's disease diagnosed once in every 15,000 admissions. This is in agree-

# SARCOMA AND PAGET'S DISEASE

ment with 1 to 10,000, in 1913, at the Johns Hopkins Hospital,<sup>30</sup> 1 to 13,000, in 1915, at Jefferson Hospital,<sup>13</sup> and 1 to 14,000, in 1938, at St. George General Hospital, Hamburg.<sup>1</sup> Bird further reported that in the Peter Bent Brigham Hospital, where 80 per cent of the admissions had roentgenograms taken, the incidence was 1 to 3,000 admissions. A recent survey at the Pennsylvania Hospital shows one case of Paget's disease in every 2,000 admissions. O'Reilly and Race,<sup>41</sup> in 1932, supplied the following interesting figures (Table I):

TABLE I  
INCIDENCE OF PAGET'S DISEASE IN VARIOUS LOCALITIES

Hospital		Incidence
Leeds General.....	1927-30	1 case in 3,700 in-patients
London Hospital.....	1926-29	1 case in 1,400 admissions
London Hospital (when bone dystrophies were under investigation)	1930-31	1 case in 260 admissions
Guys Hospital (Orthopedic Department).....		1 case in 130 cases treated
Devonshire Hospital for Rheumatic Diseases—Buxton.....		1 case in 170 cases

In making routine bone examinations, 1933-38, Abel and Hellwagen<sup>1</sup> found one case of Paget's disease in every 1,400 specimens examined. Campbell and Whitfield,<sup>9</sup> in 1943, reported one case in 650 patients examined roentgenologically at the Albany Hospital. Schmorl,<sup>53</sup> in 1932, examining the skeletal systems of all his autopsies on patients over 40 years of age, for a period of five years, found that 3 per cent showed Paget's disease (138 cases in 4,614 autopsies). It seems from the foregoing results that as more roentgenograms are taken, and more special bone studies are being made, more cases of Paget's disease are being diagnosed. It may be that the disease is far more common than we suspect, especially the monostotic type of Paget's disease, where the diagnosis is much more difficult.

## INCIDENCE OF SARCOMATOUS DEGENERATION IN BONES AFFECTED WITH PAGET'S DISEASE

Sir James Paget was able to observe 23 cases of osteitis deformans during his lifetime, and eight of these he was able to follow to their death. Of the eight, five died with malignant lesions—three carcinomas, one sarcoma, and one unspecified, which was probably sarcoma. He suggested the possibility that "by some gradual general change the osteitis made the patient very liable to cancer or sarcoma."<sup>45</sup> Since his time, numerous case reports emphasize the tendency to sarcomatous degeneration of bones affected by Paget's disease. Packard, Steele and Kirkbride<sup>42</sup> collected 67 cases of osteitis deformans from the literature, five (7.5 per cent) of which died with sarcoma of bone. Bird<sup>3</sup> reported an incidence of 11 per cent in the cases of osteitis deformans which he collected, Grunner, Scrimger and Foster<sup>24</sup> 9 per cent, and Geschicker and Copeland<sup>19</sup> 5 to 7 per cent. Codman,<sup>11</sup> quoting Bird and Sosman, gives an incidence of 12-14 per cent. Coley and Sharp<sup>12</sup>, in reviewing 72 cases of osteogenic sarcoma in patients over 50 years of age, found that Paget's disease was the predisposing factor in 28 per cent. Moore<sup>39</sup> states that 25 per cent of patients over 50 years of age, having osteogenic sarcoma, are affected with Paget's disease. It was suggested by Abel

and Hellwegen<sup>1</sup> that sarcomatous degeneration is so frequent in bones affected by Paget's disease as to warrant periodic roentgenologic studies on all patients with this disease, in order to find the sarcomas early, when they occur.

While most Americans and some Europeans accept the complication of sarcomatous degeneration of bone in 5 to 14 per cent of patients with Paget's disease, others have a different idea. Knaggs,<sup>35</sup> in a study of osteitis deformans in 1926, expressed the opinion that "the frequency of sarcomatous degeneration of bone as a complication had been accidentally exaggerated." Speiser<sup>58</sup> found sarcoma in only 2 per cent of patients with osteitis deformans, yet, he still acknowledged that sarcoma of bone occurs about 30 times more frequently in patients with Paget's disease than in the osseous structures of the general population in the same age groups. Sear,<sup>55</sup> reporting on cases in Australia, where Paget's disease is so frequent, found sarcoma in only 2 per cent of several hundred cases. He reported that he doubted if there was any relationship between the two diseases. Schurch and Uehlinger,<sup>54</sup> in their study, found an association of the two conditions so infrequently that they concluded: "Osteitis deformans may, therefore, not be designated as pre-sarcomatous or precancerous."

#### RELATIONSHIP OF PAGET'S DISEASE TO OSTEOGENIC SARCOMA

If we accept the view that osteitis deformans enhances sarcomatous degeneration of bones, as evidence undoubtedly seems to favor, then what is the explanation? Some are convinced that trauma is the precipitating factor. A fair percentage of cases of osteogenic sarcoma is reported following minor trauma to bones affected by Paget's disease, but in more cases there is no history of injury. Some cases are reported as sarcoma beginning after fracture of a bone showing osteitis deformans. Others report perfect healing of this type of fracture. Stohr<sup>59</sup> reported 12 cases of fracture of a long bone showing Paget's disease, all of which healed normally, without one developing sarcoma.

Does Paget's disease, itself, predispose to sarcomatous degeneration of bone? It was pointed out by Coley and Sharp,<sup>12</sup> and has numerous times been confirmed, that patients with Paget's disease and sarcoma of bone invariably have the tumor in bones definitely showing osteitis deformans. Von Albertini<sup>62</sup> described a "presarcomatous change" in the bone marrow of multiple bones in a long-standing case of Paget's disease. There was a predominance of large spindle cells which did not invade or destroy the surrounding tissue. He considered this an intermediate stage between the supposed chronic inflammation of Paget's disease and the highly malignant sarcoma found in other affected bones of the same individual. Speed<sup>26</sup> suggests the possibility that "in bones subject to the change of Paget's disease, one might expect a more frequent development of osteogenic sarcoma than in normal bones, because of the substitution with softer and osteoid type of bone, a tissue of younger type, more active cellularly than normal bone—which heals readily after traumatic fracture, as shown by many reports of Paget's disease.

This osteoid tissue has a less chronologic age and subsequently may, and probably does, undergo malignant change more frequently than normal bone." Jaffe<sup>31</sup> believes it quite likely that the tremendous proliferative capacity of the tissue involved in polyostotic Paget's disease may, in itself, be the basic stimulus for tumor formation.

#### CHARACTERISTICS OF COMPLICATING SARCOMA OF BONE

Sarcomas of bone are notoriously varied in histologic structure, and despite numerous attempts, no classification is widely considered adequate. The bone sarcomas complicating Paget's disease are not unlike the uncomplicated sarcomas of bone affecting the general population. Osteogenic sarcoma is the classical example and is predominantly subgrouped as spindle cell sarcoma, mixed cell sarcoma, round cell sarcoma, *etc.* It is interesting to note in six instances (including one case reported at this time) that fibrosarcoma is the histologic type reported. Whether or not these fibrosarcomas take origin from the periosteum, endosteum, or from the abnormally increased fibrous tissue element of Paget's disease is not known. Since these tumors are so few, and since they are so different from those sarcomas arising from osteoblastic tissue, it is questionable whether or not the six fibrosarcomas should be considered in the same category with the large number of true osteogenic sarcomas complicating Paget's disease.

Unlike uncomplicated osteogenic sarcoma, those secondary to osteitis deformans have the peculiar characteristic of often affecting multiple bones of the same individual. Twenty-six of the 76 collected cases (Table II) are known to show sarcoma in multiple bones. This multiple bone involvement is considered by some to be metastasis from one primary site. However, this seems unlikely since only those bones affected by Paget's disease show sarcomatous change and multiple bones may be affected without the lungs, liver, brain, and other viscera being involved.<sup>52, 12, 14</sup>

*Age Incidence.*—Osteitis deformans is a disease found in the older age-group. It is rarely seen under 40 years of age. Although Da Costa, *et al*<sup>13</sup> reported a case of Paget's disease beginning at the age of eight, and Jaffe<sup>31</sup> another beginning at the age of 28, these are extremely rare. Schmorl<sup>53</sup> reported that he had never seen osteitis deformans in any form under age 40. Packard, Steele, and Kirkbride,<sup>42</sup> in their analysis of 51 cases of osteitis deformans collected from the literature, found the average age of onset to be 49.5 years. The span of time between the beginning of the osteitis deformans and the onset of sarcoma is unknown. In Table III, the 76 collected cases of sarcoma of bone complicating Paget's disease have the ages recorded in 74 instances. The average age is 57.7 years—the youngest being 32 years and the oldest 78 years. This shows a difference of over eight years between the average age of onset of Paget's disease, as recorded by Packard, Steele, and Kirkbride, and the average age of onset of the complicating sarcoma in the collected cases.



TABLE II

COLLECTED CASES OF SARCOMA COMPLICATING PAGET'S DISEASE\*

Author	Year	Age	Sex	Paget's Disease Sarcoma		Location and Histologic Diagnosis of Sarcoma
				Mono-	Poly-	
1. Paget (Case 1)	1877	68	M	P	M	Fibrosarcoma of left radius
2. Paget (Case 2)	1877	60	M	P	M	Sarcoma of humerus (no histologic examination made)
3. Howse (cited by Speiser)	1877	65	M	M	M	Spindle cell sarcoma of tibia
4. Goodhart	1878	60	F	P	P	Medullary sarcoma of skull, pelvis, and vertebral column
5. Fielder	1896	45	F	P	M	Mixed spindle and round cell sarcoma about sacro-iliac joint
6. Wherry	1896	56	M	P	P	Periosteal sarcoma of skull and tibia
7. Packard, Steele, and Kirkbride	1901	65	M	P	M	Giant cell sarcoma of skull
8. Von Kutscha	1909	56	F	P	P	Sarcoma of tibia and skull
9. Gruner, Scrimger, and Foster	1912	56	M	P	P	Spindle cell sarcoma of shoulder and radius
10. Ransohoff	1913	49	M	?	M	Round cell sarcoma of tibia
11. Heazlitt	1917	40	M	P	M	Giant cell sarcoma of tibia
12. Carman and Carrick	1921	62	M	P	M	Mixed cell sarcoma of femur
13. Fedder (autopsy by Christeller)	1924	50	M	P	P	Round cell sarcoma of femur, humerus, skull, ribs, and vertebra
14. Camp (Case 1)	1924	70	M	P	M	Sarcoma of femur (no histologic examination made)
15. Camp (Case 2)	1925	60	M	P	M	Osteogenic sarcoma of humerus
16. Cabot	1926	43	M	P	M	Osteogenic sarcoma of neck of femur
17. Pick-Martens (personal communication with Janker)	1926	57	M	P	M	Sarcoma of humerus (rich in cells and with giant cells)
18. Bird (Case 1)	1927	66	F	P	M	Fibrosarcoma of skull with bone formation
19. Bird (Case 2)	1927	60	M	P	M	Sarcoma of ileum (no histologic examination made)
20. Bird (Case 3)	1927	60	M	P	M	Fibrosarcoma of elbow
21. Bird (Case 4)	1927	69	M	P	M	Osteosarcoma of humerus
22. Bird (Case 5)	1927	55	M	P	P	Osteogenic sarcoma of ileum
23. Bird (Case 6)	1927	44	M	P	M	Osteogenic sarcoma of clavicle and scapula
24. Bird (Case 7)	1927	69	M	M	M	Fibrosarcoma of skull
25. Bird (Case 8)	1927	56	M	P	M	Osteogenic sarcoma of femur
26. Bird (Case 9)	1927	45	M	P	P	Osteogenic sarcoma of humerus and tibia
27. Gold	1927	63	M	M	M	Round cell sarcoma of humerus
28. Looser	1928	50	M	P	M	Spindle cell sarcoma of femur
29. Poro (cited by Segale)	1928	66	M	P	M	Spindle cell sarcoma of scapula
30. Segale	1928	50	M	P	M	Round and spindle cell sarcoma humerus
31. Speiser (also published by Albertini)	1928	51	M	P	P	Mixed cell sarcoma of femur and tibia (principally spindle cells with few giant cells)
32. Stohr	1929	72	M	P	M	Mixed cell sarcoma of humerus (principally spindle cell)
33. Wissing (Case 1—autopsy by L. Pick)	1929	53	M	P	P	Round cell sarcoma of clavicle
34. Wissing (Case 2—autopsy by L. Pick)	1929	64	M	P	P	Partly medullary, partly round to mixed cell sarcoma of left foot and skull
35. Genner and Boas	1930	51	M	P	P	Large cell medullary polymorphonuclear sarcoma of scapula, clavicle, and humerus
36. Mathey-Cornat	1930	42	M	?	M	Chondrosarcoma of scapula
37. Ochsner and Gage	1930	61	M	P	M	Osteogenic sarcoma of tibia
38. Breslich	1931	61	M	P	M	Osteogenic sarcoma of tibia
39. Coley and Sharp (Case 1)	1931	63	M	P	P	Osteogenic sarcoma of femur with metastasis to humerus

# SARCOMA AND PAGET'S DISEASE

TABLE II (Continued)  
COLLECTED CASES OF SARCOMA COMPLICATING PAGET'S DISEASE\*

Author	Year	Age	Sex	Paget's Disease Sarcoma		Location and Histologic Diagnosis of Sarcoma
				Mono-	Poly-	
				ostotic		
40. Coley and Sharp (Case 2)	1931	66	M	P	P	Osteogenic sarcoma of tibia, ulna, and humerus
41. Coley and Sharp (Case 3)	1931	57	M	P	M	Osteosarcoma of humerus and femur
42. Volkmann	1931	53	M	P	P	Spindle cell sarcoma of femur (generalized but only femur histologically proved)
43. Smith	1931	51	M	P	M	Osteogenic sarcoma
44. Gougerot, Isay and Stehelin	1931	?	?	M	M	Polymorphic sarcoma of humerus
45. Wanke	1932	68	M	P	P	Osteochondrosarcoma of femur with multiple primary sarcoma nodules
46. Schmorl (personal communication with Wanke)	1932	63	?	P	P	Multiple sarcoma
47. Gerstel and Janker	1933	78	M	M	M	Spindle cell sarcoma of skull with giant cells
48. Hagenau, Gally, and Daum	1934	62	M	M	P	Osteosarcoma of humerus and femora
49. Perlman	1934	54	M	M	M	Sarcoma which varies from polymorphonuclear to spindle cells of the lower end of the femur and other points
50. Bauzet, Delarue, and Elbim	1935	61	M	P	M	Osteogenic sarcoma of femur
51. Kienbock and Selka	1935	47	M	P	P	Polymorphic sarcoma (with ossification of vertebral column, 6th rib, ilium, and femur
52. Parenti and Ludeke	1935	67	M	M	P	Spindle cell and polymorphic sarcoma of tibia with multiple nodules in other bones
53. Grizaud	1936	32	M	P	M	Sarcoma of femur (no histologic examination made)
54. Jeanneney and Cretin	1936	68	M	P	M	Osteogenic sarcoma of humerus
55. Davie and Cooke (Case 1)	1937	64	F	P	P	Spindle cell sarcoma of humerus and skull
56. Davie and Cooke (Case 2)	1937	42	M	P	P	Spindle cell sarcoma of ulna, vertebral column, femur, and skull
57. Abel and Hellweg	1938	76	M	M	M	Osteoid sarcoma of ilium
58. Rinonapoli	1938	61	M	P	M	Spindle cell sarcoma of humerus
59. Schurch and Uehlinger	1938	55	M	P	M	Osteogenic sarcoma of femur
60. Regan	1938	?	M	P	M	Sarcoma of skull
61. Vater and Abel	1939	63	M	P	P	Osteogenic sarcoma of femur
62. Hansen	1941	52	M	P	M	Osteogenic sarcoma of humerus
63. Speed†	1941	58	F	P	P	Osteogenic sarcoma of tibia, femur, pelvis, scapula, and lumbar vertebrae
64. Metz†	1941	53	M	M	M	Bone sarcoma of radius
65. Meyerding†	1941	44	M	M	M	Giant cell sarcoma of femur
66. Schajowicz	1942	48	M	M	M	Chondrosarcoma
67. Pike (Case 1)	1943	53	M	P	M	Osteogenic sarcoma of lesser trochanter of femur, involving sacrum
68. Pike (Case 2)	1943	62	M	P	M	Osteogenic sarcoma of scapula
69. Pike (Case 3)	1943	63	F	P	M	Osteogenic sarcoma of femur
70. Campbell and Whitfield (Case 1)	1943	52	M	P	M	Chondrosarcoma of sacrum
71. Campbell and Whitfield (Case 2)	1943	53	M	P	P	Osteogenic sarcoma of 6th and 7th thoracic vertebrae
72. Campbell and Whitfield (Case 3)	1943	64	F	P	M	Sarcoma (?) 6th dorsal vertebra (roentgenogram diagnosis only)
73. Kirschbaum	1943	78	F	P	M	Sclerosing fibrosarcoma of skull
74. Authors' (Case 1)	1945	44	F	P	M	Osteogenic sarcoma of tibia
75. Authors' (Case 2)	1945	66	F	P	P	Osteogenic sarcoma of humerus and skull
76. Authors' (Case 3)	1945	50	F	P	P	Fibrosarcoma of skull, ribs, vertebrae, and femur

\* This table was revised and 20 new cases added to the one published by Schajowicz.<sup>52</sup>

† Included in article by Hansen.<sup>28</sup>

*Sex Incidence.*—In uncomplicated Paget's disease, Bird<sup>3</sup> gives a proportion of 65 males to 35 females. Schmorl<sup>153</sup> gives 58 males to 42 females. O'Reilly and Race<sup>41</sup> think the sexes are affected equally. In the 74 instances of the 76 collected cases of Paget's sarcoma, where the sex is recorded, 62 (84 per cent) are males and 12 (16 per cent) females. Three of the 12 females are reported in this article. Schajowicz<sup>52</sup> suggested that the prognosis of Paget's disease in women was better than that in men, because the incidence of sarcomatous degeneration reported was much greater in men than women.

#### LOCALIZATION OF PAGET'S SARCOMA

Table III gives an estimate as to the frequency of involvement of the individual bones with Paget's sarcoma in the collected cases (Table II). All the cases could not be included because a few of the authors did not specify the exact bones harboring the sarcoma.

TABLE III  
LOCALIZATION OF PAGET'S SARCOMA

	Femur	Humerus	Skull	Tibia	Scapula	Vertebrae	Ilium	Ribs	Pelvis	Radius	Ulna	Sacrum	Clavicle
Monostotic sarcoma	11	11	6	6	3	1	3	0	0	2	0	1	0
Polyostotic sarcoma	13	9	9	7	3	5	3	3	3	1	2	0	3
Total	24	20	15	13	6	6	6	3	3	3	2	1	3

*Treatment.*—The prognosis in sarcoma of bone complicating Paget's disease is extremely grave. There is no known cure. When possible, early amputation well above the sarcomatous bone, with or without previous roentgenotherapy, seems to be the treatment of choice. For those cases where amputation is impossible, roentgenotherapy seems beneficial. Although the roentgen ray does not stop the growth of the lesion, it often renders the patient free from pain during the terminal stages. Cordotomy has been resorted to in some instances. It was pointed out by Coley and Sharp that those patients having osteogenic sarcoma secondary to Paget's disease have a life expectancy ten months shorter than those with uncomplicated osteogenic sarcoma of the same age-group.

#### ILLUSTRATIVE CASE REPORTS

Case 1.—G. L., white, female, age 49, was admitted to the Surgical Service of Dr. W. E. Lee, at the Pennsylvania Hospital, on January 18, 1944, with the chief complaint of a large painful swelling on the right lower leg. Three months prior to admission she received an injury to her right ankle which seemed unimportant at the time, but after several weeks there appeared a swelling on the medial aspect which gradually increased in size. Five weeks before admission the tumor had become very large, was reddened, and painful. Her local doctor made a small incision in this area and found spongy friable tissue, which bled profusely. There was a large hemorrhage each time the dressings were changed, thereafter.

Significant physical findings were an extremely thin, pale, emaciated white female. There was prominence of the frontal and temporal bones and the eyes were sunken

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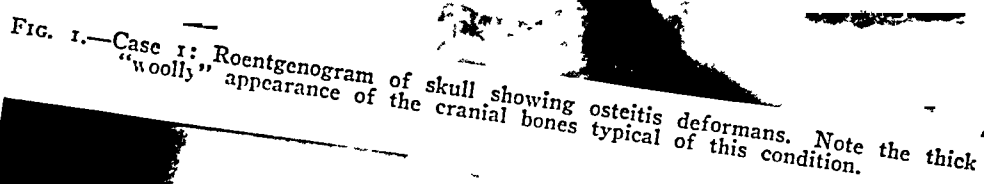


FIG. 1.—Case 1: Roentgenogram of skull showing osteitis deformans. Note the thick "woolly" appearance of the cranial bones typical of this condition.

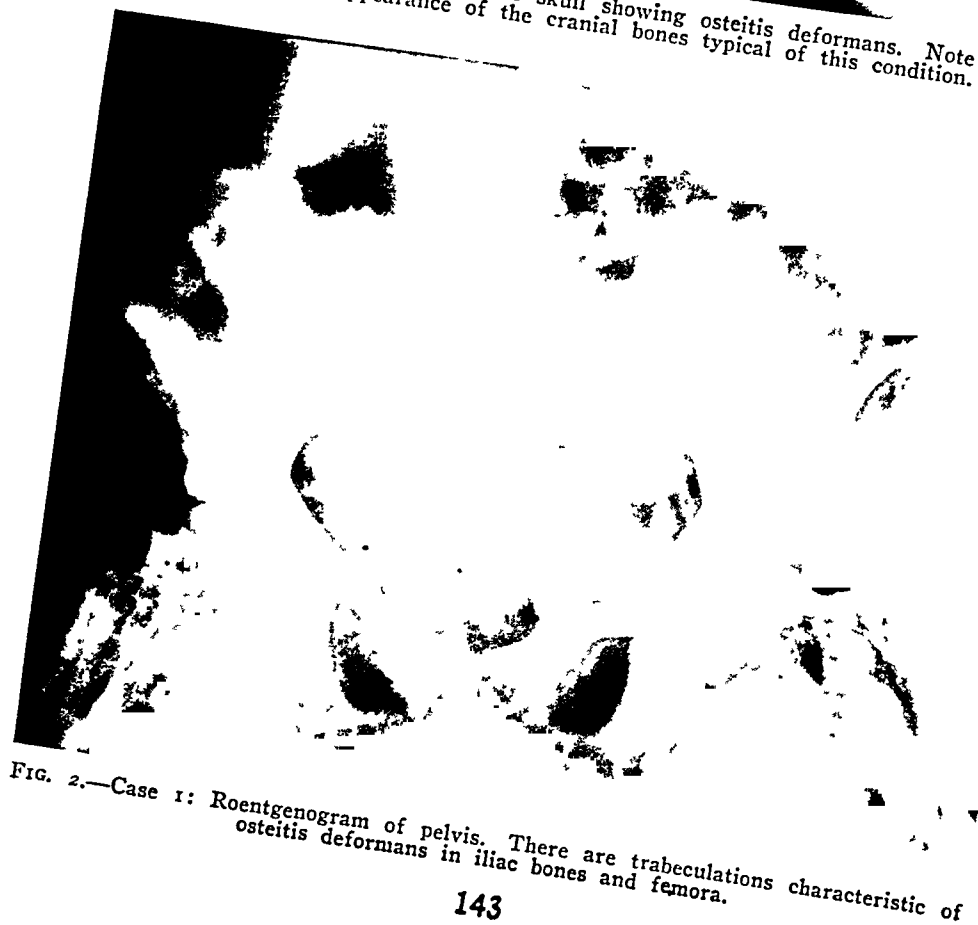


FIG. 2.—Case 1: Roentgenogram of pelvis. There are trabeculations characteristic of osteitis deformans in iliac bones and femora.

bilaterally. Mucous membranes were generally pale. Over the right internal malleolus was a tumor mass bulging outward 8 by 7 cm., which projected 2 cm. above the surrounding skin. It was ulcerated, red, soft, and bled easily. The ankle and foot were edematous, red and hot. The tibia was roughened and bowed anteriorly. There was marked edema of both hands and arms, and the left foot and leg to the knee.



FIG. 3

FIG. 4

FIG. 3.—Case 1: Roentgenogram of bones of leg. Note the marked bowing of the right tibia with rearrangement of trabeculation. The sarcoma is at the lower third of the right tibia.

FIG. 4.—Case 1: Roentgenogram showing osteogenic sarcoma. Note the bone destruction in the tibia with calcification in the soft tissue.

Pertinent laboratory findings were hemoglobin of 8 Gm., erythrocytes 2,400,000, leukocytes 25,000, with 92 per cent polymorphonuclear cells, 6 per cent lymphocytes, and 2 per cent basophils. Wassermann reaction was negative. Total protein was 3.6 per cent, hematocrit 22.3 volumes per cent, phosphorus 2.3 mg./100 cc., calcium 10.4 mg./100 cc., and alkaline phosphatase 21.4 units. (Bodansky)

Roentgenograms showed changes typical of osteitis deformans in the long bones of both lower legs, pelvis, and upper ends of both femora and the skull; and helped to confirm the already suspected diagnosis of osteogenic sarcoma of the left tibia. Preoperatively, she was treated with a high protein, high caloric diet with vitamin supplements, and 1,500 cc. of whole blood and 250 cc. of plasma intravenously.

On January 25, 1944, a low thigh amputation of the right leg was performed under spinal anesthesia, by one of us (T. J. S.). Five hundred cubic centimeters of blood and 250 cc. of plasma were given at operation. Her postoperative course was uneventful, and she was discharged much improved on the thirteenth postoperative day. She was seen periodically in the Out-patient Clinic. In July, 1944, she suddenly became ill from "heart trouble" and died four days later at home. No necropsy was obtained.

Summary of histologic report of surgical specimen (Dr. John T. Bauer, pathologist). (See Figures 5 and 6 for photographs of gross specimen.): Microscopically, the epithelium

covering the tumor was extremely thin, having been attenuated by the underlying neoplasm. The tumor was growing wildly and consisted of irregular fibroblasts, poorly defined pale masses of a typical osteoid tissue with occasional calcification, and loose reticular tissue in which could be seen irregular bizarre-shaped cells with hyperchromatic nuclei of various sizes and shapes. Many multinucleated cells were present. Many abnormal



FIG. 5

FIG. 5.—Case 1: Photograph of right leg after amputation.



FIG. 6

FIG. 6.—Case 1: Photograph showing the sarcoma after longitudinal section (posterior view).

dividing cells existed. Vacuolated macrophages were present in the edematous cystic spaces formed by the tumor, and in the more cellular areas macrophages were filled with blood pigment. In some areas there were giant cells which contained a dozen and more regular small oval nuclei, similar to those seen in benign giant cell tumor. About some of the small islands of osteoid tissue, osteoblasts were recognized.

A section of the tibia taken from an area above the sarcoma showed a thickening

of the cortex. Numerous trabeculae were present. There was an irregular arrangement of the lamellar systems, giving a "mosaic" structure typical of Paget's disease. There was an increased amount of fibrous tissue between the trabeculae. Both osteoblasts and osteoclasts were numerous. The normal constituents of the marrow cavity had been replaced by fibrous tissue which was surrounded by a pale eosinophilic staining network of bone. *Pathologic Diagnoses:* Osteogenic sarcoma of right tibia. Paget's disease right tibia.

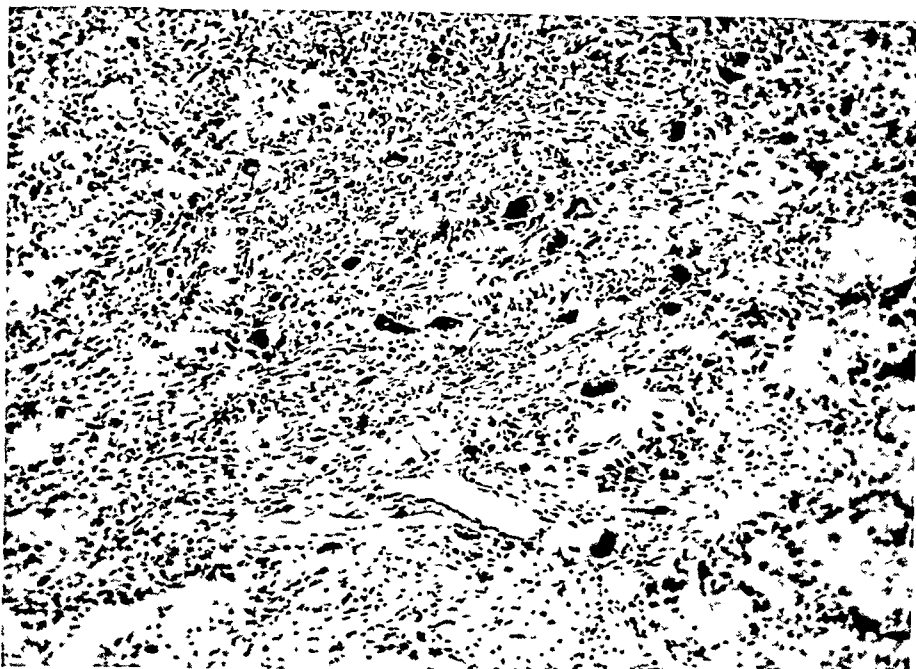


FIG. 7.—Case 1: Photomicrograph showing osteogenic sarcoma. (X 120)

Case 2.—M. K., white, female, age 66, was admitted to the Surgical Service of Dr. W. E. Lee, at the Pennsylvania Hospital, on February 19, 1938, with a chief complaint of a painful swelling of the left arm following an injury four months previously. The immediate reaction was slight but two days later the elbow began to swell and she noticed mild pain in the area. The swelling and tenderness gradually progressed until, at the time of admission, there was a knot the size of a hen's egg on the lower internal aspect of the humerus. She had lost 20 pounds of weight in two months.

Significant physical findings were as follows: Patient was an emaciated white female, apparently chronically ill; eyes were sunken symmetrically. The left elbow showed a fusiform swelling, mostly on the medial aspect. The skin over it was tense and somewhat reddened. The area was hard, not movable, and no pulsations were felt or bruits heard. There was no axillary adenopathy. Flexion and extension of the elbow were limited, but pronation and supination of the hand were normal.

Pertinent laboratory findings were calcium 10.0, phosphorus 3.4, serum alkaline phosphatase 0.70 mg./cc. (Hunsberger method), and Wassermann reaction negative.

Roentgenograms showed well-advanced typical changes of osteitis deformans, or Paget's disease, in the left humerus, pelvis and skull, and confirmed the clinical impression of sarcoma of the left humerus.

She refused operation at this time and was discharged on March 10, 1938, but returned two weeks later with more severe pain, a more advanced lesion and, therefore, consented to operation.

On March 26, 1938, under gas-ether anesthesia, the left arm was disarticulated at

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the shoulder joint by one of us (T. J. S.). Her postoperative course was uneventful, and she was discharged on April 20, 1938, to be followed in the Out-patient Clinic.

She was readmitted to the hospital on August 1, 1938, because of a painful lump, 3 x 10 cm., on the back of the head in the suboccipital region, and numerous smaller

FIG. 8

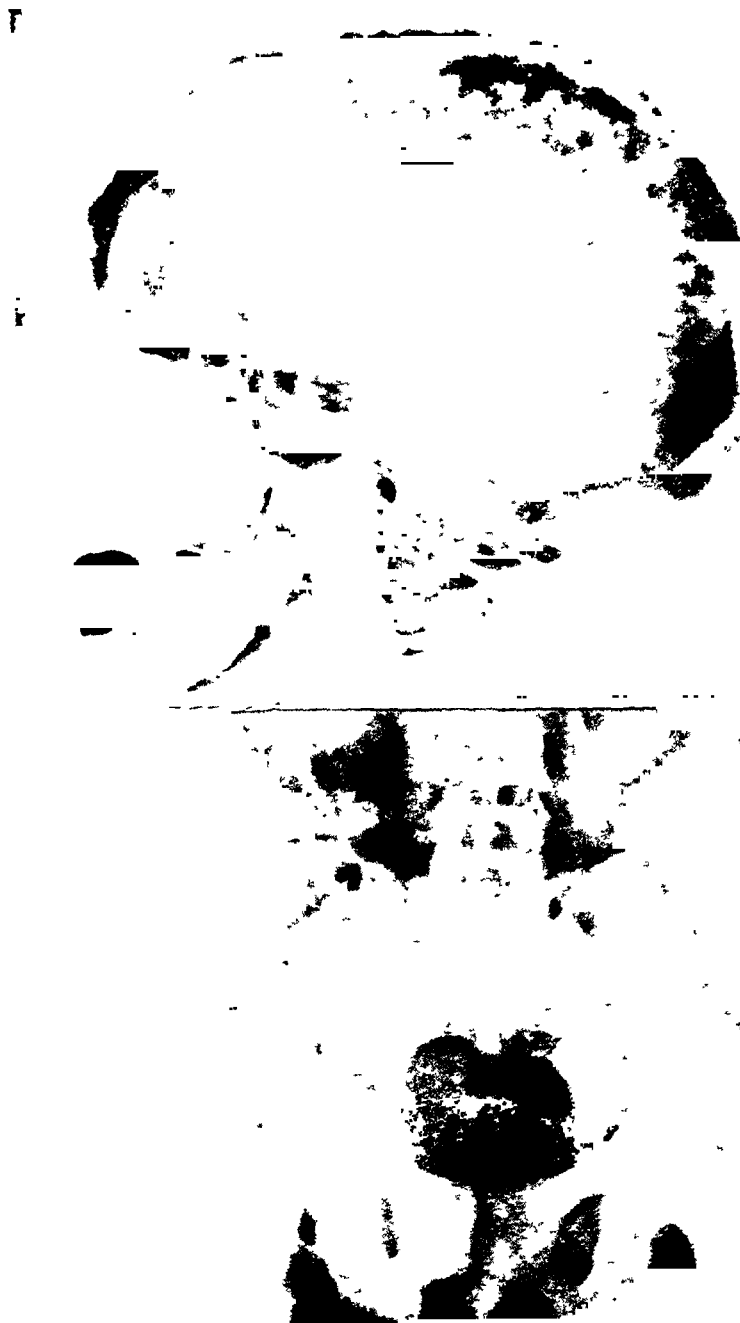


FIG. 9

FIG. 8.—Case 2: Roentgenogram of skull showing osteitis deformans.  
FIG. 9.—Case 2: Roentgenogram of pelvis showing osteitis deformans.

masses on the skull. The corneal reflex (V) was absent on the left side and blurring of the right disk was noted; physiologic cupping was absent in both disks. There was a complete peripheral type facial (VII) nerve paralysis on the left. Roentgenograms



of the skull showed a rounded area of demineralization in the temporal region which was not present on the preceding examination. The lesion was compatible with osteogenic sarcoma of the skull (metastasis?). The lungs were again negative for any evidence of metastasis. After a steady downhill course she died on September 5, 1938.

Photographs of the gross specimen as removed may be seen in Figures 11 and 12. Microscopically, a section through the midshaft of the humerus showed considerable thickening of the cortex with narrowing of the medullary cavity. The cortex had lost its dense character and the architecture was disorganized. Only a few poorly formed haversian canals remained in the outer part of the cortex. There was extensive re-



FIG. 10.—Case 2: Roentgenogram showing osteogenic sarcoma of humerus four months after onset of symptoms. Note the changes of osteitis deformans in the humerus proximal to the sarcoma.

absorption of normal bone by osteoclasts which were present in great numbers. At the same time, there was excessive formation of irregular bony lamellae by osteoblasts. The marrow had lost its blood forming elements and had become converted into a loose vascular fibrous tissue. In the tumor proper there was a proliferation of connective tissue passing through the stages of spindle cell osteoblasts and new bone. The osteoblasts were irregular in size and shape, many of them being pointed in one direction so that they looked like tadpoles. Their cytoplasm was hyperchromatic and their nuclei were oval, vesicular, and deep-staining. Some osteoblasts contained two or more nuclei and occasional mitotic figures were seen among them. The new bone spicules were of irregular shape and many of them were covered by the malignant osteoblasts. The osteoblasts occurred between the spicules as well. In the spicules the osteocytes were of

## SARCOMA AND PAGET'S DISEASE

irregular shape and hyperchromatic. There were occasional spicules of dark-staining osteoid tissue. A few areas of necrosis were seen and these were infiltrated with polymorphonuclear cells. *Pathologic Diagnoses:* Paget's disease of left humerus. Osteogenic sarcoma of left humerus.

FIG. 11

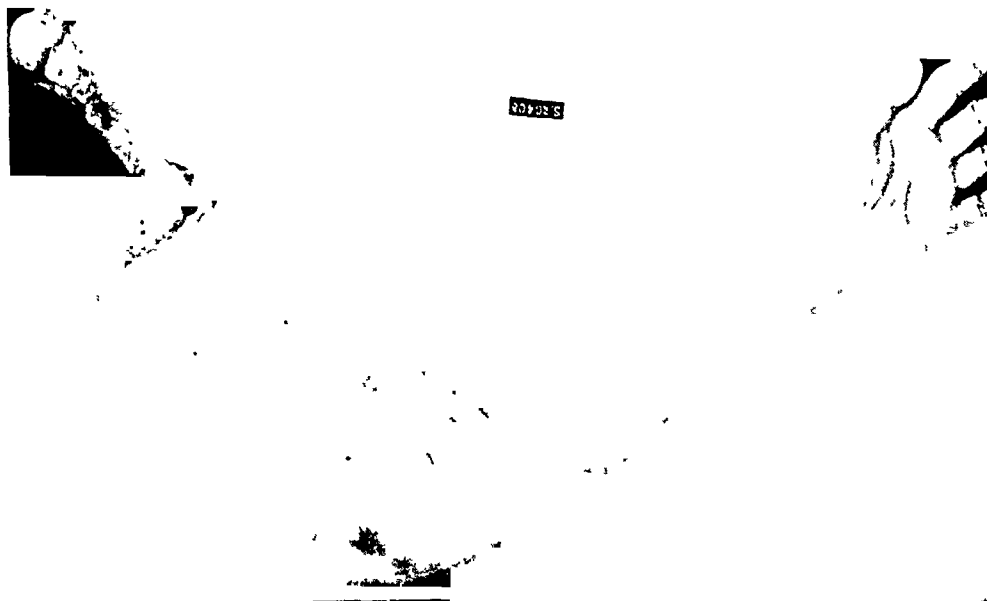


FIG. 12

FIG. 11.—Case 2: Photograph showing left arm after disarticulation at the shoulder joint.  
FIG. 12.—Case 2: Photograph of osteogenic sarcoma after longitudinal section (posterior view). Reprinted by permission, Archives of Surgery.

Summary of pertinent findings at necropsy, performed on September 5, 1938: The skull was thickened diffusely but was thicker in some areas than in others. In the thicker areas of diploe small nodules of firm, rubbery, grayish-white tissue extended both internally and externally from the skull. Some of these compressed the seventh, eighth, and ninth nerves on the left side and involved probably the third and fifth nerves

as well at the base of the brain. Microscopically, the lesions were typical of Paget's disease, with a great deal of new bone formation as well as bone resorption. In some areas the marrow was filled with fibrous tissue. Osteoblasts and osteoclasts were both numerous. In the softer tumor-like areas great proliferation of osteoblastic tissue was present with the deposition of hyaline matrix which was not yet calcified. The cells in these areas were definitely hyperchromatic and anaplastic. Mitotic figures were numerous and multinucleated giant cells were scattered among the smaller osteoblasts. These resembled osteoclasts rather than undivided osteoblasts. Compared with the specimen removed surgically, these nodules and changes in the skull itself were practically identical to those of the humerus. There were no metastases to other portions of the body and, so far as could be determined pathologically, the other bones were unaffected by the process. There was a widespread arteriosclerosis and arteriolosclerosis of the spleen and pancreas. *Pathologic Diagnoses:* Paget's disease of the skull. Osteogenic sarcoma of skull, with compression of left 7th and 8th cranial nerves.

Case 3.—B. F., colored, female, age 50, was admitted to the Norris Medical Service, at the Pennsylvania Hospital, on November 22, 1928. The chief complaint was frequent episodes of nausea with blood-tinged vomitus, and a feeling of weakness and malaise for seven days. She had a mass in the left upper quadrant which she had known to be present for two years, and which had grown steadily in size. This proved to be a large spleen extending to the level of the umbilicus. The liver was not palpable. After studies were completed, the diagnosis lay between splenic anemia (Banti's disease) and myeloid leukemia in the aleukemic phase. After further study as an out-patient, she was readmitted, and the spleen removed on March 20, 1929.

The symptoms subsided remarkably following splenectomy, but after further study, as an out-patient, the diagnosis of chronic myeloid leukemia was established. She was readmitted to the medical service on November 6, 1935, because of progressive pain and weakness of the legs for four months. Pertinent physical findings at this time were a prominent forehead with the temples having a "sunken" appearance. There was a nodule, 1 cm. square, just below the hair border on the right forehead. It was stony-hard and firmly fixed to the bone. There was a generalized lymphadenopathy with hard, discrete, moderately enlarged nodes in the anterior and posterior cervical chains, axillary areas, inguinal areas, and the epitrochlear area on the right. A 3 x 3 x 3 cm. stony-hard nodule was fixed to the second left rib near the costochondral junction. The liver was palpable almost to the symphysis pubis, with the edges smooth and rounded.

Roentgenograms of the chest showed a cardiac enlargement, with lymph node enlargement in each hilus. Examination of the bones showed the ribs to contain numerous areas of rarefaction. These changes were also noted in both scapulae and multiple areas of rarefaction were seen about many of the long bones, especially marked about the knees. There was some thickening of the cortices, evidently due to periosteal reaction. The skull was thicker than normal. After a gradual downhill course the patient died on February 17, 1936.

At necropsy, significant findings were numerous tiny nodules in or beneath the skin of the legs and abdomen. There was a firm white button-like mass on the right frontal bone, firmly attached, which did not impinge upon the brain. The entire skull was thicker than normal. There was a hard white mass firmly attached to the left second rib near the costochondral junction and a similar mass attached to the left femur. The marrow of the ribs, vertebral bodies, and left femur was dull-gray and more abundant than usual. The liver was greatly enlarged. Masses of firm white tissue were seen about the celiac axis, pancreas, and aorta, and similar ones invading the parietal peritoneum, liver, right kidney pelvis and the walls of the left auricle of the heart. Lymph nodes in the abdomen and chest were generally enlarged.

Microscopically, the bone tumors showed many very small spindle-shaped cells with darkly-staining nuclei and a few large multinucleated cells with acidophilic

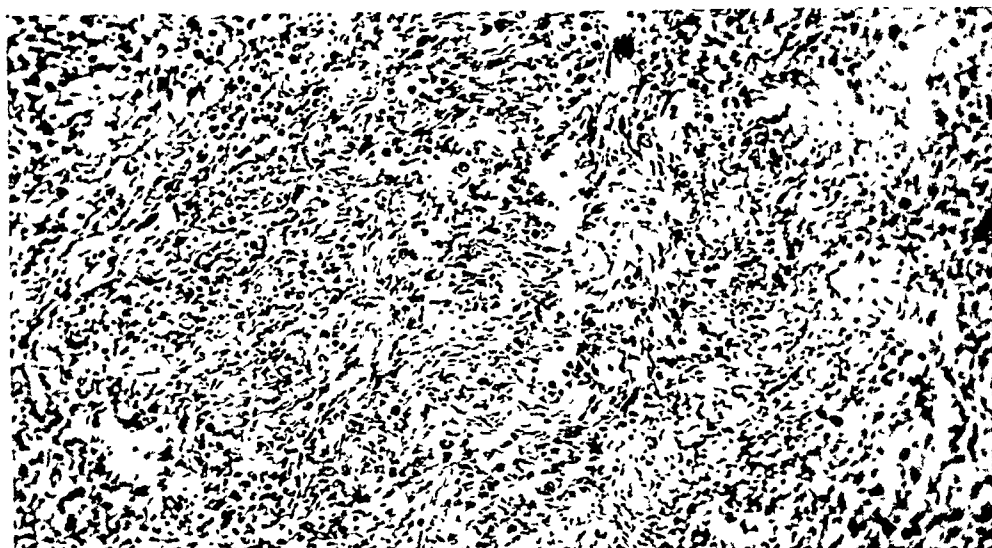


FIG. 13.—Case 2: Photomicrograph showing osteogenic sarcoma. ( $\times 120$ )

FIG. 14

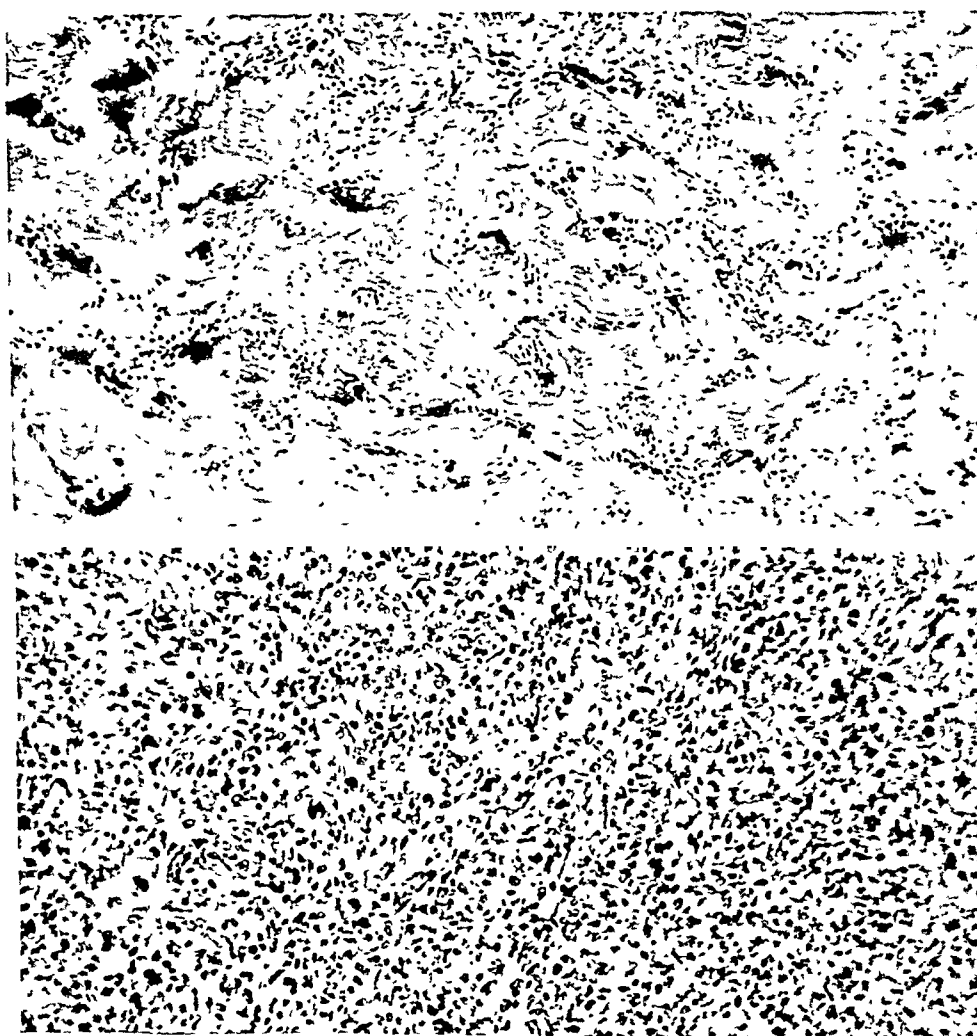


FIG. 15

FIG. 14.—Case 3: Photomicrograph showing osteitis deformans. ( $\times 120$ )  
FIG. 15.—Case 3: Photomicrograph showing fibrosarcoma. ( $\times 120$ )

cytoplasm. Some of the cells had indefinite cell bodies resembling in some instances fibroblasts with pale vesicular nuclei. The cells showed marked variation in size and shape. Mitotic figures were seen. Fibrous tissue stroma was scanty. There was bone destruction by the tumors but no evidence of osteogenic activity by the neoplastic cells. Sections of these bones taken from areas not involved by the tumors showed thickening of the cortices, with increased trabeculations and increased fibrous tissue proliferation. The white tumor masses described in and about the viscera had a structure similar to that of the bone tumors and apparently were metastases. Postmortem studies of the blood and bone marrow proved the presence of abnormal cells of the granulocytic series compatible with chronic myeloid leukemia. *Pathologic Diagnoses:* Paget's disease, with osteogenic sarcoma of skull, femur, ribs, and vertebrae. Chronic myeloid leukemia.

## SUMMARY

1. The clinical and microscopic picture of Paget's disease is given, with a brief discussion as to its nature and the possible etiologic factors.

2. The frequency of diagnosis of Paget's disease seems to vary directly with the number of roentgenograms taken and the number of gross and microscopic bone studies made.

3. There seems to be a definite relationship between osteitis deformans and sarcomatous degeneration of bone. The incidence of bone sarcoma secondary to Paget's disease is given as 2 to 14 per cent; however, some authors deny any relationship between the two diseases.

4. Certain characteristics are peculiar to Paget's sarcoma:

(a) It is usually found in patients over age 40.

(b) The sarcoma often involves multiple bones simultaneously.

(c) Only bones showing osteitis deformans show the sarcoma.

5. The prognosis is very grave, and there is no known cure.

6. Three cases of sarcoma complicating Paget's disease are reported.

7. The literature is reviewed, and an attempt is made to record all the cases of sarcoma complicating Paget's disease reported to date.

We wish to express our appreciation to Dr. John T. Bauer for his help in preparing this paper.

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# EXTRADURAL SPINAL HEMORRHAGE

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CHICAGO, ILL.

THE INDIVIDUAL SURGEON must have a very limited experience with extradural spinal hemorrhage, for references to it in the literature are hard to find. It is of special significance on account of the fact that in contradistinction to the usual type of injury of the spinal cord with paraplegia, in this particular syndrome prompt recovery of function is to be expected if a proper diagnosis is made and operation is undertaken at the earliest possible moment.

**Case Report.**—L. R. a 75-year-old white male, was admitted to the Presbyterian Hospital at 9:45 P. M. on February 18, 1943. That afternoon at 3:30 P. M. he fell four or five feet striking upon his buttocks, and after a few moments he got up and walked up 14 steps into the house. A few minutes later, while sitting in a chair, he felt severe pain in the upper part of his back and down both arms; he then walked to the bathroom and took some medicine to relieve the pain and then returned to the chair. The pain was not relieved, and with help he went upstairs to bed. About half an hour after the accident, while lying in bed, he noticed that his legs were getting weak, and after a few more minutes found himself unable to move them. Numbness in the legs, in the abdomen, and in the chest accompanied the weakness in the legs. The arms were also somewhat numb and the strength in them was diminished. He was taken to the Presbyterian Hospital, where he was seen at 10:00 P. M.

On examination, the patient was alert and coöperative, but unable to make any movement with his legs. There was a sensory level on the trunk at the junction of the third and fourth cervical nerves with the third thoracic segment; on the hands there was an uncertain sensory level at the seventh or eighth cervical segment. Muscular power was entirely lost in the legs and in the trunk, but he could move his arms. There was slight weakness of the biceps muscles, and the triceps muscles were much weaker. He was unable to spread the fingers in either hand, in other words, the interossei were paralyzed, but he was able to use the thumb and the flexors of the fingers in both hands with some diminution in strength. The biceps reflex was present bilaterally; neither triceps reflex was obtained. There was urinary retention and a bilateral Babinski sign. The patient had had an arthritis of the spine for many years and there was a deformity of the whole trunk and neck which were bowed stiffly forward. An attempt was made to do a spinal puncture but, owing to the solid arthritis of the spine, it was impossible to enter the spinal canal. The blood pressure on admission was 120/80 mm. Hg.; temperature 100.4° F.; respiration 22; pulse 100.

Operation was decided upon because of the progressive signs. The patient was first taken to the Roentgenologic Department where anteroposterior and lateral views of the cervical spine were taken. There was complete fusion of all the cervical vertebrae, which was regarded as a Marie-Strumple type of arthritis; there was no fracture-dislocation. A diagnosis of fracture dislocation with compression of the spinal cord at the eighth cervical segment was made before the roentgenograms were seen. Massive extrusion of a cervical intervertebral disk was also considered before reading the roentgenograms, but after these were seen (Fig. 1), it was felt that the most likely diagnosis was extradural hemorrhage of the spinal cord.

**Operation.**—There were numerous difficulties in operating upon this patient because of the ankylosing arthritis of the spine. The head could not be extended which suggested that there would be difficulty in introducing the intratracheal tube. As a matter of fact, in this position this was found to be easy. The sitting position for operations upon

## EXTRADURAL SPINAL HEMORRHAGE

the cervical spine, usually adopted here, was not considered feasible and the patient was placed face down in a cerebellar head rest. A midline incision was made over the spinous processes of sixth and seventh cervical and the first thoracic vertebrae. The spinous processes and laminae were exposed and the laminae of the first thoracic and the seventh cervical vertebrae were removed. As the lamina of the seventh cervical vertebra was removed, there was evidence of an extradural hemorrhage. The laminae of the sixth and the fifth vertebrae were also removed exposing the extradural clot (Fig. 2), which measured approximately  $4 \times 2 \times 1$  cm. The clot was lifted out in one piece (Fig. 3).



FIG. 1.—Lateral view of the cervical spine showing Marie-Strumpel's type of arthritis, and a coin used as a marker. Lower views revealed no fracture-dislocation.

Following this the dura began to pulsate freely, but there was some bleeding from sclerotic extradural vessels. Muscle was packed in over the bleeding vessels and an iodoform gauze drain was led down to the dura. In this elderly man it was thought to be too time-consuming to stop the bleeding points individually. The wound was closed hurriedly with silkworm gut sutures. An indwelling catheter was inserted immediately after operation.

He was alert and coöperative throughout his convalescence, and there was rapid



improvement in his neurologic condition. By noon of the day following the operation he could make slight voluntary movements of his feet and he could feel the pinprick down to the level of the twelfth thoracic segment. Two days after the operation, the patient could feel the pinprick down to the third lumbar segment, but there was no sensation in the legs below the knee; he had developed more movements in the lower extremities. Three days after the operation, the pinprick was felt over the entire body and movement of the lower extremities was complete, though weak; there were some involuntary twitchings of the left leg. The temperature rose to 103.6° F. in 12 hours following

operation but then remained between 101° F. and normal until the seventh postoperative day, after which it remained normal. The blood pressure remained rather low, 100/50 mm. Hg., or so, for the first four postoperative days and then gradually rose to 130/60 mm. Hg., where it remained during his stay in the hospital. The catheter was removed on the fourth postoperative day, but the patient was unable to void; it was reinserted and left in place until two days before he left the hospital on March 8. During the last week in hospital he continued to improve and was up in a chair every day. He was sent home in the care of his family doctor, who stated that after a few days he was gradually able to walk about and, as his strength improved, he resumed his usual occupation.

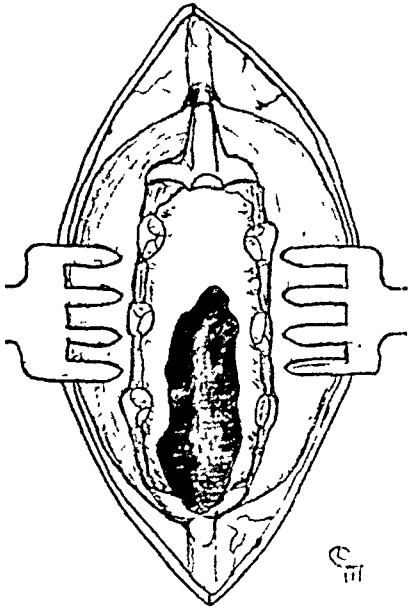


FIG. 2.—Operative sketch by Captain Charles S. Textor II.

COMMENT.—The most important point in the consideration of this case was that of deciding to operate upon the patient immediately. This, in turn, depended on

establishing a correct diagnosis, which was strongly suggested by the history. In spinal cord injuries it has always been my practice to wait for spinal shock to pass off before considering operative measures. The freedom, for a time, from paralysis, and then its gradual onset suggested an hemorrhagic type of lesion, which it turned out to be. Before the roentgenograms were taken the possibility of a fracture-dislocation occurring in two stages was considered, as was the possibility of severe injury to the neck, with partial displacement of an intervertebral disk subsequently further displaced by movement, resulting in massive extrusion and compression of the cord. The roentgenograms, however, did away with these possibilities, for it seemed impossible for a dislocation to occur or for a nucleus pulposus to herniate in the ankylosed condition of the cervical spine. The most likely possibility, apart from the hematomyelia, was extradural hemorrhage.

It had been my opinion that the condition, though rare, was occasionally seen, but reference to the literature revealed only a few cases. They are of two kinds: those that occurred "spontaneously" and those that occurred as the result of injury. The word hematorrachis was used to describe some of them. Some of the case reports were difficult to evaluate because of incomplete pathologic or operative reports. For the purpose of this discussion only

those cases of extradural spinal hemorrhage in which the lesion is solely responsible for paraplegia will be considered; there is often both intradural and extradural bleeding in fracture-dislocation of the spine, but these are not the cause of the paraplegia that follows the injury.

The first two cases reported were apparently both "spontaneous" extra-dural hemorrhages, or hematorrachis, as they were called. In 1897, William Bain<sup>1</sup> reported the case of a young housemaid who had suffered for years from constipation. On this particular morning she had great difficulty in moving her bowels. Half an hour later she had severe pain in her back, arms, and legs. She was seen by Bain two hours later, who found that she now had a quadriplegia; she died a respiratory death while he was there.

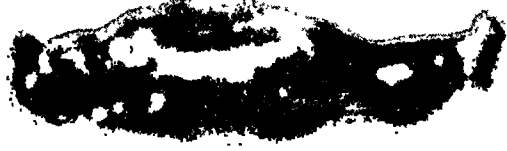


FIG. 3.—Extradural clot removed from under the fifth and sixth cervical laminae.

At postmortem examination an extradural clot was found under the second and third cervical vertebrae. Bain specifically stated that all the other organs were healthy and that the rest of the spinal column was normal. The second case was reported by S. D. Hopkins in 1899, who quoted Bain. This was the case of a middle-aged man, who while shoveling coal, suddenly felt a severe pain in his back. There was severe pain down the legs and tingling sensations. In 20 minutes he could not move his legs. Twenty-four hours later some movement returned in the left leg, but he remained incontinent of urine and feces. Four days after this incident he died, and at autopsy an extradural hemorrhage was found in the lumbar region.

In 1911, A. F. Jonas,<sup>7</sup> in presenting a paper on spinal fractures before the American Surgical Association, mentioned the case of a 35-year-old farmer, who, ten days before he saw him, had fallen ten feet out of a hay loft. Jonas thought that motor power had been lost immediately and that sensation had been lost gradually over 24 hours. Operation was immediately undertaken (*i.e.*, when seen ten days after the injury), and an extradural clot was found under the fifth and sixth thoracic vertebrae. There is no mention of a fracture-dislocation. The patient recovered function in his legs. It is of interest that Dr. Harvey Cushing was present at this meeting and that he discussed Dr. Jonas' paper at some length.

In 1925, J. Reid and J. Kennedy<sup>9</sup> described the case of a young woman who fell off her bicycle on September 6, 1925. Witnesses stated that this was a very slight injury, actually she was pushed off her bicycle by a car travelling at about five miles per hour. On September 7 and 8 she had pain in the legs and back; on September 9 she walked into the doctor's office;

on September 10 she developed a flaccid paralysis, and on September 11 she died a respiratory death. At postmortem examination an extensive extradural hemorrhage was found from the lumbar region to the third cervical vertebra; there was no fracture-dislocation.

In 1935, Hassin and Stone<sup>5</sup> reported the case of a 32-year-old woman who developed a clumsy and awkward gait two weeks after a normal delivery. This became progressively worse, and the extremities gradually grew rigid, so that the patient frequently fell. Two days after such a fall the patient developed retention of urine and a dull aching pain was felt in the inguinal region. The lower extremities were paralyzed except for some movements in thighs and there was great rigidity. Beever's sign was present and the lower abdominal reflexes were absent, the upper extremities appeared normal. Changes in sensibility were inconspicuous except for loss of vibration sense to just below the knees in both legs. Spinal puncture revealed a complete block. A diagnosis was made of subacute combined degeneration of the cord with extradural neoplasm at the level of the tenth thoracic segment. At laminectomy, an extradural clot, which resembled a cyst, and which measured 2 x 2 x 1.5 cm., was removed at that segmental level. There was no fracture-dislocation. The patient improved, and at a later date manometric studies showed an absence of spinal block. She died two weeks after operation, with increasing pallor and marked shortness of breath.

In 1941, Wortis and Sharp<sup>10</sup> mentioned extradural hemorrhage in a table in an article entitled "Study of 200 Cases of Spinal Fracture." In this case the hemorrhage was probably not the primary cause of the paraplegia.

Spontaneous extradural hemorrhage causing cord compression is said to occur in hemophilia, and W. M. Priest<sup>8</sup> described such a case in 1935. There was, however, no direct confirmation of this diagnosis either by operation or autopsy. Charles H. Frazier's<sup>4</sup> text book on "Spinal Cord Surgery" contains only a reference to Jonas,<sup>7</sup> and Elsborg's<sup>3</sup> book does not refer to this syndrome at all. It is mentioned as an entity in Osler's Modern Medicine, 1928, in the chapter written by Sir F. Farquhar Buzzard and C. P. Symonds,<sup>2</sup> but no case is quoted, nor is a reference given.

In considering the etiology of these eight cases available in the literature, those of Bain<sup>1</sup> and of Hopkins,<sup>6</sup> and that of W. M. Priest<sup>8</sup> are of the so-called spontaneous variety. Priest's case is too poorly documented to be of value. In the case tabulated by Wortis and Sharp<sup>10</sup> the extradural hemorrhage was probably only an incidental finding. Trauma may have been of etiologic significance in the case reported by Reid and Kennedy,<sup>9</sup> and in the case described by Hassin and Stone.<sup>5</sup> Jonas' case was certainly secondary to trauma, although the title "Spinal Fractures" is misleading for no fracture was demonstrated in this instance.

The example of extradural spinal hemorrhage reported here did not have a fractured spine and it was improbable that fracture-dislocation could have occurred because of the diffuse ankylosis of the spine. Further, in the two

cases pertinent to this discussion, that of Jonas and that of Reid and Kennedy, a fracture-dislocation of the spine was not found.

Following indirect trauma to the spine, the short progressive history, with the gradual onset of paraplegia in a few minutes or a few hours, and the absence of a bony lesion should strongly suggest extradural hemorrhage of the spinal cord. At all events immediate operation should be performed at the site indicated by the motor and sensory level. A case of extradural spinal hemorrhage is reported in which early operation and removal of the clot was followed by recovery.

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East Washington Square, Philadelphia, Pa.

## BOOK REVIEW

IN THE DOCTOR'S OFFICE. By Esther Jane Parsons. Philadelphia, J. B. Lippincott Co., 295 pages, \$2.00, 1945.

Here is something worth while! Esther Parsons, as a result of personal observation and experience, is certainly qualified to compile a record of her association with many of our most meticulous professional men. How one can so interestingly and exhaustively set forth the detailed requirements of "a medical assistant" is beyond the reviewer. Certainly, anyone having all the attributes suggested by the author must be a paragon. Nevertheless, the subject matter is most essential for the office assistant to be conversant with, no matter what phase of their duties may be involved.

In addition to the myriad of details essential to the proper conduct relative to the approach to the patient, relation to the doctor, keeping of records, laboratory work, *etc., etc.*, the author has included two Chapters (XIII and XIV) on the "Preparation of Manuscripts" and on the fact that "Doctors Will Write," both of which may be studied by any essayist with advantage both to *himself* and to the reader, to say nothing of the Managing Editor, the compositor, and to the publishing house to which the article has been submitted.

In short, Esther Parsons is to be congratulated on her excellent compilation of essential data necessary for the production of an efficient "medical assistant," and much that the doctor himself may profit by. It is gladly recommended to anyone seeking proficiency in an essential position, and as a guide to a properly conducted office.

JAMES T. PILCHER, M.D.

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## ANNOUNCEMENT

The Samuel D. Gross Prize for 1945, in the amount of \$1,500.00. has been awarded to Dr. Robert Elman, of St. Louis, Missouri, for his essay entitled, "Parenteral Alimentation in Surgery: With Special Reference to Protein and Amino-acids."

Others who submitted essays may arrange for their return, if desired, by communicating with Dr. Calvin M. Smyth, Jr., Methodist Hospital, Broad and Wolf Streets, Philadelphia 48, Pa.

Office of Secretary,  
Philadelphia Academy of Surgery.

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## ERRATUM

On the Contents Page of the November issue of the ANNALS OF SURGERY, the paper entitled "A Comparative Study of 100 Fractures of the Shaft of the Femur in which One-Half were Treated with Penicillin," should have been credited to Dr. Spencer A. Collom, M.C., A.U.S., and William McDaniel Ewing, Major, M.C., A.U.S., instead of to Doctor Collom alone. The paper on "Thoraco-abdominal Injuries" is by Reeve H. Betts, Major, M.C., A.U.S.

VASCULAR INJURIES OF THE EXTREMITIES  
IN BATTLE CASUALTIESMAJOR CHARLES A. ROSE, M.C., A.U.S.,  
CORNELL, NEW YORKCAPTAIN ORVAN W. HESS, M.C., A.U.S.,  
NEW HAVEN, CONN.

AND

LT. COL. CHARLES STUART WELCH, M.C., A.U.S.  
ALBANY, NEW YORK

THE TREATMENT OF PATIENTS with arterial injury has presented a particularly difficult problem for the military surgeon. It became evident early in this war that ligation of the large arteries of the lower extremity resulted in a disappointingly high incidence of gangrene, and that the outlook in such cases was not as hopeful as had been anticipated. Predictions of extremity survival after arterial ligation based on experience with vascular surgery in civilian life cannot be applied to patients with vascular wounds in warfare. In civilian practice one is more frequently dealing with the treatment of vascular lesions of some duration, in which collateral circulation has been established to some extent, making ligation less hazardous. Elective arterial ligations cannot be compared with immediate ligations for severed arteries in extremities in which extensive soft-tissue and bone damage, with destruction of collateral vessels, is present. Furthermore, the beneficial effect on collateral circulation of measures directed toward promoting vasodilatation cannot be expected to pertain so effectively in these severe injuries. On the other hand, the difficulties in vascular surgery among battle casualties has been a stimulus for the application of all established methods of treatment and for the introduction of new procedures. The use of sulfonamides and penicillin in battle casualties today, resulting as it has in a low incidence of wound infection, has made possible attempts to save extremities deprived of their blood supply, which, in World War I, would have been considered for early amputation as a prophylaxis against gas gangrene. The surgeon working in the forward areas today, therefore, has had a larger proportion of patients with damaged arteries in which restoration or improvement of the existing circulation has been the paramount problem.

In this communication we shall report our experiences in the management of 100 consecutive patients with arterial injuries of the extremities encountered in an Evacuation Hospital during an 11-month period in the campaign in Northern Europe. Only the major arteries will be considered: In the upper

extremity, the axillary and brachial arteries; in the lower extremity, the femoral and popliteal arteries. Earlier experience in the North African and Sicilian campaigns had shown us that a special study of these cases was indicated and special forms for recording pertinent data were instituted in the hospital. The results which we shall present are the immediate results given in terms of gross survival or death of some part of an extremity. All patients who left the hospital with viable extremities were classified as good results. Wherever there was evidence of impaired circulation or gangrene, the case was classified as a poor result, without qualification. We cannot report the late results in terms of the extent of limb loss, since follow-up studies are not available at this time. The period of hospitalization for these patients varied from one to 14 days and did not, as a rule, extend beyond the time required to determine the status of the extremity after surgery. As soon as adequate circulation was assured the patient was sent to the rear. If gangrene ensued, amputation was performed at once in the moist and gas-infected cases, but a line of demarcation was awaited in nontoxic patients, some of whom were sent to the rear unamputated after a period of seven to ten days of observation.

#### DIAGNOSIS

The diagnosis of arterial injury in extremities in most cases was not difficult. Certainly, the diagnosis was easy for the surgeon in those patients with free arterial bleeding who were admitted to the hospital with a tourniquet in place. However, we have found in our hospital that one must be especially on the look-out for these injuries so that no time be lost in the preparation of these patients for surgery. Whenever the diagnosis was missed, it was usually the result of inadequate examination during periods when large numbers of casualties arrived at the same time. In echelons forward of the hospital greater emphasis could be placed profitably on diagnosis of vascular injuries and patients with these wounds should be sorted out there for direct evacuation to the hospital. Palpation of pulsations in the extremity with comparison between those in both limbs should be enough to make a tentative diagnosis; certainly, all suspicious cases could be gathered together in this manner.

The presence, unilaterally, of a cold, pulseless extremity distal to a wound is an obvious indication of arterial injury. However, in two types of cases the diagnosis is less obvious. Badly shocked patients with no palpable peripheral pulsations in any extremity must be reexamined frequently for evidence of arterial injury as their condition improves. In addition, it is possible to have palpable distal pulsations in cases of small lacerations of arteries. The most easily overlooked cases are those in which the color and warmth of the extremity seem normal at the first cursory examination. A routine search for pulsations in both extremities prevents mistakes in diagnosis in the patient with a pulseless extremity of normal appearance. The Tycos sphygmomanometer, used as an oscillometer, is helpful in detecting feeble pulsations. An additional sign of value in suspected vascular injuries is the presence of a firm swelling in the region of a small wound and particularly in the region of the popliteal space and of Scarpa's triangle. Hematomas which are the

result of injury to a vein rarely cause arterial compression even in such a closed space as the popliteal fossa. In each case suspected of arterial injury a rough neurologic examination for sensation and motor function should be made if practicable. Injury of nerves is frequently associated with arterial damage since these two structures are in close anatomic association. In some cases arterial wounds may exist without being suspected by examination before operation. In those instances in which metallic foreign bodies appear to be lodged near major vessels in the roentgenograms, a careful exploration at débridement will sometimes detect small arterial lacerations. Routine palpation for thrills and auscultation for bruits indicative of arteriovenous fistulae should be a part of every examination in wounds suspected of major vessel injury. It is rare, however, to find the classical signs of arterial aneurysm or arteriovenous fistula early after injury. In only one case in this group were the classical signs present.

#### PREOPERATIVE TREATMENT

It is especially important in vascular injuries to prepare the patient for operation as expeditiously as possible since time is such an important factor in saving extremities. The circulating volume of blood should be restored as completely as possible so that the extremity need not labor under the additional handicap of blood with a decreased oxygen-carrying capacity.

Plasma was used in the preoperative treatment in 52 of the 100 cases, and had been given for the most part at the Battalion Aid or Clearing Station prior to admission as a means of temporarily combating shock so that the patient could be transported to the hospital. In the preoperative and shock wards it was used in the treatment of patients in mild shock and those in whom there had been little loss of blood.

Blood transfusions were begun immediately in the hospital. Many of these patients had lost upwards of two liters of blood and shock was frequently severe. Patients with vascular injuries were found to require much more blood than the majority of other wounded. The best guides for shock therapy were the blood pressure values and the hematocrit readings. Not infrequently, because of severe shock, operation could not be performed at the optimum time and saving the extremity was secondary to saving life. This was especially true in patients with multiple wounds. Blood transfusions of 500 cc. to 3,000 cc. were given to 55 of the 100 patients.

The urgent problem of active arterial hemorrhage in the preoperative period did not arise too frequently since the soft-tissues usually controlled external bleeding and hematoma formation resulted. When it did occur, it was usually the result of a rise in the patient's blood pressure while he was being treated for shock with blood transfusions. If the bleeding vessel could not be visualized and controlled quickly, a blood pressure cuff tourniquet was applied. Tourniquets were ordinarily released every 10 to 15 minutes. In order to avoid the prolonged use of tourniquets, transfusions of blood were given under pressure and the patient brought to surgery as soon as possible. At times it was necessary to move the patient to the operating room while



he was in shock, and, under anesthesia, control the bleeding vessel, after which the major operation could be delayed until the optimum time. The use of tourniquets is sometimes unavoidable, especially during the period before the patient reaches the hospital. They are used, however, more frequently than necessary, and have been known to do a great deal of harm. Direct pressure dressings in the wound or the application of hemostats to vessels are much more efficient and desirable methods for controlling bleeding in the usual case.

Oxygen was used routinely during the preoperative period in patients in shock in order to maintain the oxygen content of the arterial blood reaching the devitalized limb by collateral circulation at as high a value as possible.

Sulfadiazine was administered by mouth in doses of one gram every four hours. All casualties had received their initial dose of four grams before reaching the hospital. Penicillin therapy was begun preoperatively, with an initial dose of 40,000 units given intramuscularly and it was continued in doses of 20,000 units every two hours. American soldiers were given one cubic centimeter of tetanus toxoid and prisoners-of-war 1,500 units of anti-tetanus serum, as a prophylaxis against tetanus.

#### OPERATIVE TREATMENT

Almost all operative procedures were undertaken under nitrous oxide-oxygen-ether anesthesia. At times anesthesia was induced with pentothal-sodium and maintained with inhalation anesthesia. If the operation was one of short duration, pentothal-sodium alone was used.

Approach to the damaged artery was made through the extended existing wound wherever possible. Since débridement of the wound tract was of primary importance, an exposure adequate enough to reveal all parts of the wound tract was made. In an extremity that could be expected to have a deficient circulation, nothing was of greater importance than the removal of all foreign material and devitalized tissue which could act as a nidus for the development of infection. In the dissection of these wounds particular care was used to avoid damage to all vascular radicles which could provide collateral routes for circulation to the extremity. If an elective wound was necessary to provide an efficient approach to the injured vessel, the débridement of the wound or wounds was completed first and clean instruments were used for the elective approach. If active bleeding was present before operation or expected in the approach to the vessel, a proximal tourniquet was used. In wounds of the proximal portion of the superficial femoral artery, it was sometimes necessary first to expose and control the common femoral artery. Rarely, the external and common iliac arteries were exposed and arterial tourniquets placed in order to avoid troublesome bleeding.

The average time between wounding and surgery was 15.5 hours. The shortest time in this group of patients was four hours and the longest 51 hours. In the following paragraphs we shall outline the various operative procedures employed and the indications used for each.

In Table I the results of the various procedures employed for each of the

several arteries are tabulated in terms of good or poor results for extremity survival.

*Primary Amputations:* In nine, or 9 per cent, of the total of 100 patients treated, primary amputation was necessary. All of these patients had wounds which were at least 16 hours old and which were extensive and complicated by the presence of a compound fracture. This group was not in the traumatic amputation classification. The major arteries were severed and thrombosed and no retrograde bleeding was present in the distal portion of the severed vessel. The portion of the extremity distal to the wound was cold and cyanotic, and in several cases early rigor had appeared. The decision to amputate was never made without consultation and if there was any question of the advisability of amputation, it was delayed for 24 hours. If amputation was necessary, it was undertaken at the lowest level possible.

*Arteriorrhaphy:* Repair of a lacerated artery was undertaken in five cases, or 5 per cent of the total. The femoral artery was repaired three times, the axillary once, and the brachial artery once. In the five patients in whom arteriorrhaphy was attempted the tissue damage was slight in three, and moderate in two. There were no associated long bone fractures and no arterial thrombosis existed.

In two of the three patients with injury of the femoral artery, the extremity had a normal appearance before operation and the dorsalis pedis and posterior tibial pulsations were present. The arterial wounds were discovered unexpectedly in the course of the débridement. The wounds extended through the intima and were one centimeter in length. With proximal and distal control of the vessels by means of soft rubber local tourniquets, suture was performed by coapting intima-to-intima with interrupted fine silk stitches, and reinforcing the latter with a row of sutures through the muscular coat. In both of these cases a good circulation was retained and the patients were transferred with distal pulsations present in warm extremities. In the third case involving the femoral artery the distal part of the extremity was cold and white, before operation, and no pulsations were palpable. The arterial wound involved the muscular layer only but the vessel was contused. The defect in the muscularis was repaired by interrupted fine silk sutures. Color, warmth and peripheral pulsations returned to the extremity after operation, and the patient was evacuated with a normal circulation in the extremity.

The wound of the axillary artery which was repaired was discovered at operation in a patient whose arm had a normal appearance and a normal radial pulsation before operation. The arterial wound was 0.5 centimeter in length and involved the muscular coat only. Repair was made with interrupted silk sutures and no impairment of circulation resulted.

The largest arterial wound repaired was a laceration of the brachial artery three centimeters in length. The patient's hand was cool and cyanotic, before operation, and no radial pulsation was present. After surgery the color and temperature returned to normal but a radial pulse was not at any time palpable and thrombosis may have occurred at the site of the repair.

Repair of a lacerated wound of an artery should be attempted in those

cases in which wounds of the extremity have only moderate tissue damage and in which the arterial wound is small and there is no marked circulatory deficiency. In these, approximation of the wound edges can be effected easily and quickly without prolonged interruption of the blood flow and without appreciable decrease in the size of the lumen by the repair. Repair of an extensive arterial wound often results in obliteration of the lumen and an arterial anastomosis is the better operation in such cases if an attempt at maintaining the arterial continuity is to be made.

*Ligation:* Ligation of the injured artery was done in 70, or 70 per cent, of the total of 100 cases. While some of these 70 cases might have had an

TABLE I  
RESULTS OF TREATMENT IN 100 PATIENTS WITH VASCULAR INJURIES

Treatment	Axillary Artery		Brachial Artery		Femoral Artery		Popliteal Artery		All Arteries	
	Good Result	Poor Result	Good Result	Poor Result	Good Result	Poor Result	Good Result	Poor Result	Good Result	Poor Result
Primary amputation	0	1	0	4	0	1	0	3	0	9
Arteriorrhaphy.....	1	0	1	0	3	0	0	0	5	0
Ligation.....	3	2	24	11	3	14	3	10	33	37
Nonsuture										
anastomosis.....	0	1	1	0	1	4	0	1	2	6
Débridement only..	0	0	1	1	1	1	4	0	6	2
Totals.....	4	4	27	16	8	20	7	14	46	54

attempted anastomosis, we were handicapped by the lack of material early in the campaign. In addition, it must be said that in busy periods with large numbers of casualties of serious nature there was insufficient time for performing long operations, the successful outcome of which was doubtful and the hazard considerable in the severely wounded. If the vessel was severed, the devitalized ends were excised and the proximal and distal ends were ligated doubly with chromic catgut sutures. If the vessel was not severed, the division was completed. Quadruple ligation was practiced as a rule, and the companion vein was similarly ligated and severed. In those arteries in which a small laceration had resulted in thrombosis of long-standing, the thrombosed section was excised and the ends were ligated.

Early in the campaign the wounds were frosted with a mixture of sulfanilamide and penicillin, but later this practice was discontinued. Elective wounds were closed in layers if the other wounds provided adequate drainage for the tract but the primary wounds were partially and loosely closed only when they had been well-extended. Loose vaselined strips were placed in the wound and covered with dry gauze dressings. The extremity was usually encased in a split-plaster encasement, whether or not a fracture was present.

Of the 70 patients in whom arterial ligations were performed, 37 had gangrene of some portion of the extremity after operation, and 33 had a viable extremity. The results after ligation varied in the case of individual arteries and are listed in Table I. In subsequent paragraphs we shall discuss the significance of arterial ligations at different anatomic levels.

*Arterial Anastomosis:* The anastomosis of severed arteries in war wounds with extensive damage to the collateral vessels would seem to be the only

method of saving some of these extremities. Suture anastomosis offers many difficulties under the best of conditions and in patients in whom extensive wounds have resulted in considerable damage to arteries the technical difficulties are increased by shortening and retraction of the vessels making approximation of the cut ends impossible without great tension. After attempting suture anastomosis of the popliteal artery, we abandoned the method as not practical in the usual type of case we encountered, and have concentrated our efforts on the nonsuture method of blood vessel anastomosis described

TABLE II  
BLAKEMORE NONSUTURE ARTERIAL ANASTOMOSIS

Case No.	Artery	Time Wounded before Surgery in Hours	Tissue Damage	Heparinized	Result in Extremity
1.	Axillary (third part)	12	Moderate	No	Gangrene
2.	Brachial, proximal to bifurcation	4	Moderate	No	Viable arm
3.	Common femoral at bifurcation	9	Moderate	Yes	Gangrene
4.	Superficial femoral	4	Slight	Yes	Gangrene
5.	Superficial femoral	9	Slight	No	Viable leg
6.	Superficial femoral	10	Moderate	No	Gangrene
7.	Superficial femoral	14	Severe	No	Gangrene
8.	Popliteal between the geniculates	10	Moderate	No	Died at operation

by Blakemore, Lord and Stefko.<sup>1</sup> During the Sicilian campaign two of these anastomoses were attempted upon patients with severed popliteal arteries not reported in this series. Both anastomoses were unsuccessful but we felt that the method was the best available and offered promise especially if cases were carefully selected and more experience gained in the technic.

Briefly stated, nonsuture blood vessel anastomosis is accomplished by bridging the gap between the severed ends of the artery by using vitallium tubes which are lined with a section of vein, usually the great saphenous. The vitallium tubes are fitted into the arterial segments to be joined and tight junction is accomplished by ligature. Suturing is avoided and a continuous intimal lining for blood flow through the bridge is provided. Excellent descriptions of the method are given in the publications of Blakemore, *et al.*<sup>1, 2, 3</sup>

We performed vitallium tube anastomosis in eight of the 100 patients in this group. The data on these patients is presented in Table II. The small number of cases in which an anastomosis was undertaken cannot be interpreted as an index of the possible application of arterial anastomosis to war wounds. We were limited in employing the method in a larger series for a number of reasons: First, we selected those in which we felt a reasonable chance for trial of the method could be obtained. Only one patient in whom there was severe tissue damage of an extremity was subjected to anastomosis and in none was there a compound fracture present. Patients who could be brought to operation as soon as possible after being wounded were taken. In Table II the time between wounding and operation is seen to be between four and 14 hours, with an average of approximately nine hours. There were two patients operated upon within four hours—the most desirable time. Unfortunately, the time factor is an uncontrollable one. On the other hand, with the exception of one case (Patient No. 2), we performed no anastomoses on

brachial arteries since we felt that anastomosis of this vessel would not be a good test of the efficiency of the method. Results after brachial artery ligation are relatively good, collateral circulation in the arm is infinitely better than in the leg, and in the absence of oscillimetric studies and arteriography we believed there might be confusion in crediting the results obtained. Finally, we were limited in our supply of vitallium tubes and heparin until the latter part of the campaign.

We found in most cases, and even in the presence of free retrograde bleeding from the severed distal end of the artery, that suction would remove a fair-sized thrombus. In two instances ureteral catheters were passed down the distal end of the artery and the vessel irrigated. Heparin was available for use in only two cases, and in these was administered by intravenous drip. In addition to heparinization of the patient, heparin was instilled directly into the artery after completion of the operation.

Vitallium tube anastomoses were performed in five patients with femoral artery injury. In four of these the superficial femoral artery was injured and in one, an anastomosis was effected after ligation of the deep femoral branch for a wound at the bifurcation of the common femoral artery. The posterior tibial and dorsalis pedis pulsations were not present in any of these patients before operation. A satisfactory anastomosis was accomplished in each case and the distal arterial segment pulsated while the anastomosis was under direct observation but at no time were the posterior tibial and the dorsalis pedis pulsations detected postoperatively. In only one of the five cases was a viable extremity obtained (Patient No. 5). This patient had been wounded nine hours previously, and, on admission, his extremity was cool but not excessively cold, and pulsations were absent. After operation the leg became warm and pink, and remained so until evacuation. In a follow-up note from the patient five months after injury he stated that his leg was entirely normal and that he was walking on it without trouble. The condition of this patient's leg before operation was such that we believe that collateral circulation may have placed a larger rôle than the anastomosis in saving the leg.

Patient No. 4 seemed to us an ideal one for trial of the method. This patient had a small clean knife wound of the superficial femoral artery in Hunter's canal. He was fully heparinized beginning at operation. After operation, the distal arterial segment presented a good pulsation. The final result, however, was gangrene of the lower leg requiring amputation at its midportion, 14 days after injury.

One anastomosis on each of a popliteal, an axillary and a brachial artery was performed. The patient in whom the popliteal artery was anastomosed (Patient No. 8) died on the operating table after operation had been completed upon being turned over on his back. Postmortem examination revealed a pulmonary artery embolus. In the case of the patient with a severed axillary artery (third portion), we had little hope of success since the forearm and hand were both extremely cold and slight mottling of the skin was already present. Amputation at midforearm was necessary ten days after operation. The one patient upon whom anastomosis of the brachial artery was done died

on the fourth day with anuria as a result of "crush" syndrome. He had been pinned under a vehicle for two and one-half hours. However, the hand and forearm were viable on the day of his death. Before operation no radial pulsation was present. Twenty-four hours postoperatively the radial pulse was palpable. In this case, however, the brachial artery had been severed just proximal to its bifurcation, a site at which ligation is usually quite safe. In fact, we have not infrequently noted that radial artery pulsations may become palpable 24 to 72 hours after ligation of the brachial artery. Postmortem examination showed that there was no thrombus in the anastomosis. Excluding the patient who died at operation, there were seven cases in which the extremities were observed postoperatively. In five, gangrene resulted and amputation was necessary. In two, a viable extremity was obtained. In both of these latter cases, however, we believe that collateral circulation was better than in the other cases in which anastomosis was performed. The failures, on the other hand, cannot be attributed to the method since a successful anastomosis will certainly deliver blood to the distal arterial segment. We are of the opinion that thrombosis and spasm in the distal arterial tree are the greatest detriments to success. Nevertheless, we believe that the method of Blakemore has certain disadvantages, especially in field surgery. The operation requires over two and frequently three hours to perform including the making of the vein graft bridge. We usually selected the great saphenous vein from the uninjured leg although femoral veins were used on two occasions. A careful débridement must be done and this is time-consuming. Early experience showed us that a smaller vitallium tube must be used than one would judge necessary or splitting of the intima of the artery will result on attempting to force a tube of desirable size into the arterial stump. The resulting diminution in the lumen at the anastomotic site is, in itself, not considered to be important since diminution in diameter has been shown experimentally to be compensated for by an increased rate of blood flow.<sup>4</sup> The segment of vein between the two vitallium tubes, however, is thin-walled and expands considerably, resulting in what might be compared to a fusiform aneurysm. It is our impression that arterial pressure is reduced in passing through the vein graft. This impression is corroborated by the appearance of the stream of blood which emerges from the distal end of the bridge, and by the fact that the pulsation in the distal segment of the artery is weaker than in the proximal segment after completion of the anastomosis. A rigid tube of metal or plastic material might overcome this objectionable feature, although we have not used such tubes.

*Conservative Treatment:* A total of eight patients with vascular injuries were treated conservatively, *i.e.*, only débridement of the wound, or wounds, was performed (see Table I).

In three cases arterial spasm was present. Two patients had spasm of the brachial artery exposed at operation. In one, there was a segment of the artery four centimeters long, proximal to the profunda branch of the brachial artery in spasm; in addition, a compound comminuted fracture of the humerus, radius and ulna were present. Perivascular infiltration with

procaine solution followed by perivascular sympathectomy failed to relieve the spasm. Postoperatively, cervical sympathetic block was performed, producing Horner's syndrome. The spasm was apparently not relieved and gas gangrene developed, requiring amputation on the third day. In the second patient, the brachial artery was in spasm below the profunda branch. The extremity was warm at all times but there was no palpable radial pulse. After operation the radial pulse became palpable following a cervical sympathetic block, and the patient was evacuated with a normal circulation in the extremity. The third instance of spasm was encountered in a patient with a shell fragment wound of the thigh in which the missile appeared, roentgenologically, to be lodged near the femoral artery. The foot was cold and white, pulsations were absent, and there was a fair-sized hematoma in the thigh. Paravertebral lumbar sympathetic ganglia block with procaine was done within four hours of injury after which the dorsalis pedis and posterior tibial pulsations became palpable. The patient was evacuated on the third day, with good circulation in the leg. It is possible that a small arterial laceration was present and that a false aneurysm or arteriovenous fistula may have later formed in the hematoma.

The fourth patient in this group, in which débridement alone was done, presented with an arteriovenous fistula of the femoral vessels in Hunter's canal. His leg and foot were warm and had good color but the peripheral pulsations were absent. Since early operation for arteriovenous fistula is not in keeping with good practice, and the patient had a viable extremity, the fistula was not explored. There were multiple leg wounds present. On the fourth postoperative day crepitation was felt in the tissues of the leg and the patient developed toxemia. The foot became cold, and it was obvious that gas-forming organisms had jeopardized the circulation. Supracondylar amputation of the femur and excision of the fistula was done, and recovery followed.

Four patients with perforating gunshot wounds of the popliteal space were treated conservatively. All showed essentially the same clinical picture throughout their stay in the hospital. On admission to the hospital, they were found to have tense hematomas and wounds of entrance and exit one centimeter to one and a half centimeters in size, located so as to indicate that the wound tract passed through the deepest part of the popliteal space. In no case was there a fracture of the femur or tibia, and all patients were in good condition. The extremities distal to the wound were warm and had good color in three patients and was cool and pale in the fourth. No dorsalis pedis or posterior tibial pulsations could be elicited in any of the patients. The skin wounds were débrided under local anesthesia. The patient with the cool foot had one lumbar sympathetic block which resulted in a warmer but still pulseless extremity that did not again become cool. No other treatment was instituted except the routine penicillin and sulfonamide therapy. The injured extremities of these four patients remained warm but pulseless during their hospital stay of seven days. Although the final examination of each patient revealed no sign of aneurysm or arteriovenous fistula, it is true that signs of

these lesions require time to develop and for this reason are infrequently diagnosed in the early period following wounding.

While it must be admitted that in these four patients with wounds of the popliteal space there is not *prima facie* evidence of an arterial wound since the vessels were not exposed, it seems reasonable to suppose that the vessel had been lacerated or severed. If the condition were spasm only in segments of these arteries, it probably would have disappeared and distal pulsations would have reappeared in 24 hours, especially in the case which had the sympathetic block. We believe that adequate circulation already existed and, therefore, surgical interference could add little to the chance of survival of the extremity.

We were led to practice this conservative method of treatment because of our experience with three similar cases in which the ligation of severed popliteal arteries resulted in an avascular extremity, in spite of preoperative evidence of adequate circulation. The reason for this occurrence of gangrene after ligation in a presumably viable leg is not clear. One might speculate that some blood reached the leg through the hematoma. The question of the ultimate fate of these extremities cannot be answered since follow-up studies are not yet complete. However, we felt justified in allowing the collateral circulation to develop even though an aneurysm or an arteriovenous fistula might develop at a later date. The only urgent indication for surgical exploration in wounds of this type is that of free bleeding. The principal danger of not performing the usual débridement is infection, and especially by gas-forming organisms. It is rather uncommon, however, for gas gangrene to develop from a perforating bullet wound in an extremity with an adequate circulation under drug therapy. These patients must be carefully observed at frequent intervals during the immediate postoperative period. Late operation for aneurysm or arteriovenous fistula must be contemplated.

#### POSTOPERATIVE TREATMENT

Routinely, penicillin and sulfonamide therapy, initiated preoperatively, was continued. Transfusions of blood were administered as indicated by hematocrit studies. The injured extremity usually was placed below the level of the heart to promote venous stasis and maintain arterial circulation at its maximum efficiency.

Alcohol, administered by mouth or intravenously, and papaverine subcutaneously were used in many cases, and a lowered temperature was maintained in the extremity in a few patients by use of the small amount of ice available. All of these measures, however, were not appreciably effective.

Block of the lumbar sympathetic ganglia with 2 per cent procaine injection was done 139 times in the 100 patients. In 25 of the 49 lower extremity cases a total of 132 blocks was performed. Cervical sympathetic block was done in five of 51 patients with upper extremity wounds. Two lumbar sympathetic ganglionectomies were done in patients with injury of the popliteal artery. The first block was usually done on the operating table at the close of the operation. This was followed-up with blocks done on the ward at



intervals of six to 12 hours. They were continued until the prognosis of the extremity was established. The question of the efficiency of each procedure cannot well be answered. In an extremity in which the distal circulation was already much impaired, a complete interruption of the sympathetic nerve pathways might show little evidence of its effect. Subjective changes were sometimes mentioned by the patient when no objective signs were evident. Because of this lack of positive evidence, the establishment of an actual block in every case cannot be affirmed. In those cases in which circulation was not markedly impaired, and in which progress to avascularity had not gone too far, the proof of an actual block was less *questionable*. The type of case in which sympathetic block was most likely to be effective rapidly and to be of unquestioned value was that of an extremity in which the artery was in spasm. One block was sufficient to change a cold, white, pulseless extremity to a more normal state of circulation. Sometimes needles were left in place after the injection of the procaine and, when the success of the block was apparent, 5 cc. of 95 per cent alcohol were injected into each needle.

In the last phase of the campaign we planned to do lumbar sympathetic ganglionectomies on selected cases in whom no contraindication to an additional operation existed. Only two were done, both in patients with wounds of the popliteal artery. One developed gas gangrene in the extremity shortly after surgery and the other patient was transferred because of rapid movement of the hospital on the fifth day, with an avascular foot. Our experience with this procedure as an adjunct has been limited to these two cases, making it impossible for us to judge its value.

We are unable to evaluate accurately the effect of the 139 sympathetic ganglion blocks on the extremity survival rate in this series of cases. One can hardly expect much of the procedure in the type of extensive injury of the extremity in which there is great damage to the collateral vessels as well as to the principal artery. There are simply an inadequate number of vessels remaining. In no case did this procedure appear to reverse the progress from an avascular state in patients with severed arteries. In almost all cases, the status of the circulation in the injured extremity was apparent at the end of the first 24 hours. In only two cases was it felt that blocking was an important factor in tipping the balance in favor of a good result.

#### GAS GANGRENE

Gas gangrene of the wound and of the extremity distal to the wound was diagnosed clinically in 12 of the 100 cases. Three were upper extremity wounds, with brachial artery injuries, and in nine the lower extremity was involved with injury of the femoral artery in five patients, and of the popliteal artery in four. The average age of the wounds at the time of operation in this group was 21.5 hours, the extremes being nine hours for the shortest period, and 48 hours for the longest. The degree of tissue damage was severe in ten wounds and moderate in two; and in 11 of the 12 cases compound fractures existed in the injured extremity. The diagnosis of gas gangrene infection was made, or suspected, in three patients at the time of the primary operation,

and amputation was performed in one case. In the remaining nine patients the infection was discovered at intervals of 12 hours to four days following operation. In four of these patients wide incision and excision of necrotic tissue was performed in an effort to save the extremity. One of these four patients died after operation, and the remaining three came to amputation at a later date. Of the total of 12 patients with gas gangrene developing in avascular extremities, 11 were subjected to amputation, and three patients died of the infection.

The recognition of gas-forming organisms as a complication was one of the most important parts of the postoperative care. The split-plaster encasement was spread widely in order to allow complete inspection of the extremity and frequent palpation for the presence of crepitus, which was one of the earliest signs of gas infection onset. In the more virulent forms of infection a severe constitutional reaction might presage its presence, but this reaction seemed to be the exception rather than the rule. Gas gangrene in the avascular extremity seldom presents the severe symptoms and signs of primary infection. The routine administration of sulfadiazine and penicillin may, in addition, have lessened the severity of the constitutional signs.

#### DEATHS

Of the 100 patients in this series, six died in the hospital. We have no knowledge at this time of subsequent deaths among the group after evacuation to hospitals in the rear. Gas gangrene was the cause of death in three cases. One of these patients died a few hours after primary amputation of a lower extremity for an extensive infection. Another patient died four hours after wide incision and excision of necrotic tissue in a leg with a widespread infective process. The third patient succumbed on the tenth day following a re-amputation in an effort to halt an anaerobic infection. A severe hemolytic blood transfusion reaction, with anuria, was the cause of death in the fourth patient. This soldier had received 2,000 cc. of blood prior to performing a celiotomy and ligation of the superficial femoral artery. Following a transfusion of 500 cc. of blood administered postoperatively, he had a severe reaction and developed renal suppression, the result of hemoglobinuric nephrosis. Death occurred on the fourth postoperative day. The fifth patient sustained a severe crushing injury of the pelvis and right lower extremity, with dislocation of the right hip joint. In addition, a lacerated wound of the left arm had severed the brachial artery. As a result of the extensive crush injury, he developed a complete anuria and died on the fourth day after operation. The sixth death occurred from massive pulmonary embolism.

DISCUSSION.—From the data presented in Table I it is evident that the prognosis for survival of extremities in which major arteries are injured is not a good one. Subjecting the data to further analysis, we have studied the results as influenced by five important factors: (1) Time factor, *i.e.*, the interval between wounding and surgery; (2) type of arterial wound; (3) degree of tissue damage; (4) anatomic location of the arterial wound; and (5) influence of treatment.

(1) *Time Factor:* In Table III we have recorded the results as good or poor for extremity survival in relation to the time-interval between wounding and operation. It is obvious that those patients in whom definitive treatment could be instituted early (one to ten hours after wounding), had the best prognosis for survival of the extremity. There are, however, a number of

TABLE III  
TIME FACTOR IN VASCULAR INJURY PROGNOSIS

	Time-interval between Wounding and Surgery	No. of Cases	Good Result	Poor Result
1.	One to 10 hours.....	31	21	10
2.	Ten to 20 hours.....	47	20	27
3.	More than 20 hours.....	22	5	17
	Totals.....	100	46	54

TABLE IV  
INFLUENCE OF TYPE OF ARTERIAL INJURY ON PROGNOSIS

	Type of Arterial Wound	No. of Cases	Good Result	Poor Result
1.	Severed.....	68	25	43
2.	Laceration.....	17	10	7
3.	Incomplete laceration.....	3	3	0
4.	Laceration, with thrombosis.....	5	2	3
5.	Spasm.....	2	1	1
6.	Not determined.....	5	5	0
	Totals.....	100	46	54

circumstances which prevent early operation after the patient enters the hospital in addition to the unavoidable evacuation time from the field. Chief among these is the presence of severe shock from loss of blood. Obviously, it is better judgment first to consider saving the patient's life rather than his extremity when too early operation would be a great hazard. In addition, delays were unavoidable when a large number of high priority cases were admitted to the hospital within a short period of time. Ideally, the length of time between being wounded and operation should be reduced. This series represents a consecutive number of patients in which all the factors of evacuation surgery problems, from the finding of the patient on the field to preparing him to withstand operation, were present.

(2) *Type of Arterial Wound:* In Table IV the results in relation to the type of arterial wound are recorded. An accompanying wound of the vein in these early cases is not ordinarily significant from the standpoint of circulation. Arterial wounds have been classified as severed when the ends were completely separated. There were 68 in this group. Lacerated wounds were those in which any part of the circumference remained intact, preventing separation, and in this series there were 17. Incomplete laceration, of which there were three examples, was considered to be a wound which did not involve the intima. When a small laceration had extended through the intima, and thrombosis had occurred both proximally and distally, the fourth category

was used. There were five cases of thrombosis. The type of injury was not determined in five cases which were not explored and arterial damage was inferred from the physical signs. In two cases of arterial spasm the arteries were visualized but no wound was discovered in them.

In Table IV it can be seen that, in general, the more severe arterial wounds resulted in a higher incidence of gangrene. Severed arteries resulted in 43 poor results out of a total of 68 cases. When the arteries were lacerated seven out of 17 resulted in loss of some part of the extremity. The degree of arterial damage was closely related to the tissue damage to the extremity.

(3) *Degree of Tissue Damage*: The effect of the severity of the wound on the circulation can be considered important from two aspects: First, because of the actual destruction of important radicles of the collateral anastomotic system; and, second, because of the systemic effect of shock and loss of blood.

The data listed in Table V indicates that the more extensive the tissue damage in the extremity, the poorer is the prognosis. In only nine of the 46

TABLE V  
INFLUENCE OF DEGREE OF TISSUE DAMAGE ON VASCULAR INJURY PROGNOSIS

Degree of Tissue Damage	No. of Cases	Good Result	Poor Result
1. Slight.....	20	17	3
2. Moderate.....	38	20	18
3. Severe.....	42	9	33
Totals.....	100	46	54

good results was there severe tissue damage, while 33 of the 54 poor results showed a severe degree of tissue damage. In addition, in only 11, or 24 per cent, of the 46 good results was a compound fracture present, while 34, or 63 per cent, of the 54 poor results had coexisting fractures.

Other wounds of the same extremity distal to the arterial injury were present in two cases in which the extremities survived and in eight in which gangrene ensued.

The type of causative missile was recorded in each case as due to gunshot, shell fragment or knife. Shell fragment wounds include those from every type of explosive missile, *i.e.*, grenade, mine, aerial-bomb, rocket and artillery shell. Two cases of knife wounds were treated, but there were no bayonet wounds. Sixty-four of the 100 wounds were caused by shell fragments and 34 by small arms missiles. Forty-six wounds were penetrating and 54 perforating in type. Neither the type of wound or the causative missile appeared to influence the result. The extent of damage to the tissues only was significant.

(4) *Anatomic Location of the Arterial Wound*: The clinical significance of the anatomic location of the arterial wound is related to collateral circulation, and for this reason a true picture of the significance of arterial severance at specific sites would require well-controlled experimental conditions. Since the time factor, degree of tissue damage, amount of blood loss, and degree of

destruction of collateral vessels are such variable factors in this study we can only arrive at the approximate significance of the anatomic site of the arterial wound. Therefore, the following figures, affected as they are by other variables, do not represent the incidence of gangrene after ligation alone.

In Table I it is obvious that wounds of the axillary and brachial arteries have a much better prognosis for survival of the extremities than wounds of the femoral and popliteal vessels. Twenty-seven of the extremities with brachial artery injury out of a total of 43 survived (63 per cent of the total). Of eight cases with axillary artery injury there were four extremities which survived (50 per cent of the total). On the other hand, only eight (29 per cent) of a total of 28 cases of injury of the femoral artery had an adequate circulation when they were transferred. Of 21 extremities with damaged popliteal arteries, seven (33 per cent) survived.

In order to arrive at some estimation of the comparative differences between arteries, insofar as the seriousness of injury to each of them is concerned, a study of those cases in which ligation was done gives the fairest picture. In Table I these figures are given. Ligation of the brachial artery resulted in the lowest incidence of gangrene and only 31 per cent of cases lost part of their extremity. Ligation of the axillary artery resulted in gangrene in 40 per cent of the cases. In the lower extremity, ligation of the popliteal artery resulted in gangrene of some portion of the leg in 77 per cent of cases, a slightly better figure than that obtained for ligations of the femoral artery (82 per cent).

The anatomic position of the wound in each artery was studied with a view to determining its significance in relation to the major collateral branches. In Table VI these results are listed.

*Axillary Artery:* In only four cases was the exact site of the axillary artery wound recorded. It was recorded as the third part of the artery in three cases, and all of these developed gangrene. The fourth patient in whom the site was recorded had a wound of the second part of the artery, and the extremity survived. No conclusions can be drawn from such a small number of cases other than the fact that in one-half of these patients gangrene of some part of the extremity ensued.

*Brachial Artery:* In injuries of the brachial artery it was possible to record the location of the wound in relation to the profunda branch but not in relation to the superior and inferior ulnar collateral branches. The latter two branches are small and it was not desirable to dissect them out for identification as a routine measure. The relation may be only inferred by the arbitrary division into proximal, middle and distal thirds of the portion of the brachial artery distal to the origin of the profunda branch. Wounds of the middle one-third probably did not involve either ulnar collateral artery. Wounds of the brachial artery appear to be most significant at one location—the origin of the profunda branch. The arterial wound involved both the brachial artery and the profunda branch in four patients, and only one arm survived. In two patients wounds destroyed the brachial artery and the

# VASCULAR INJURIES OF EXTREMITIES

proximal portions of the radial and ulnar arteries, and gangrene ensued in both cases. In both of these extensive tissue damage was present, and in one a primary amputation was performed. In the other, the wound was so extensive that little hope was held for its survival.

*Femoral Artery:* From Table VI it can be seen that gangrene resulted in all wounds of the common femoral artery, and also in two cases in which the

TABLE VI  
INFLUENCE OF ANATOMIC LOCATION OF ARTERIAL WOUND ON PROGNOSIS

Anatomic Location of the Arterial Wound	No. of Cases	Good Results	Poor Results
1. Axillary artery.			
a. Second part.....	1	1	0
b. Third part.....	3	0	3
c. Location not stated.....	4	3	1
Totals.....	8	4	4
2. Brachial artery.			
a. Proximal to profunda branch.....	4	3	1
b. At origin of profunda branch.....	4	1	3
c. Distal to profunda branch:			
Proximal one-third.....	10	6	4
Middle one-third.....	13	9	4
Distal one-third.....	12	8	4
Totals.....	43	27	16
3. Femoral artery:			
a. Common femoral.....	5	0	5
b. At origin of profunda branch.....	2	0	2
c. Superficial femoral:			
Proximal half.....	9	3	6
Distal half.....	12	5	7
Totals.....	28	8	20
4. Popliteal artery:			
a. Involving the superior geniculate branches.....	7	0	7
b. Involving the inferior geniculate branches.....	6	0	6
c. Between the geniculate branches.....	4	3	1
d. Wound not explored.....	4	4	0
Totals.....	21	7	14
Totals.....	100	46	54

common femoral and the profunda branch were involved. However, the line of demarcation in three of the common femoral cases was observed to be at or below the ankle while the level of gangrene in extremities with superficial femoral artery injuries was usually half way between knee and ankle. The survival of eight extremities out of a total of 21 with wounds of the superficial femoral artery indicates the importance of the profunda branch in maintaining collateral circulation. Holman<sup>5</sup> has stated that the blind segment of an artery between the site of ligation and the proximal major collateral branch acts detrimentally to the establishment of collateral circulation through that major branch. In our series the location of the wound in the superficial femoral artery was divided arbitrarily into proximal and distal halves with

the idea of determining the influence of this factor. In this series there were three (33 per cent) survivals in a total of nine wounds of the proximal half of the superficial femoral artery, and five viable extremities (42 per cent), resulting from a total of 12 wounds of the distal half of the artery. We would point out again, however, that the type of case with which we have experience has a number of complicating factors, because of the injury which make observations of this nature less reliable than in the case of elective operations for aneurysm and arteriovenous fistula.

*Popliteal Artery:* From Table VI it can be seen that in the seven cases in which either the superior or inferior geniculate branches of the popliteal artery were involved with the popliteal artery, gangrene ensued. Wounds of the midportion of the artery in which the geniculate branches were spared resulted in a survival of three extremities of a total of four. The four cases in which the wound was not explored might be added inferentially to the group without geniculate damage.

(5) *Influence of Treatment:* The principal accomplishment in these patients with major artery injury has been the saving of life by prompt and adequate treatment of shock and the prevention of serious infection by débridement. Gas gangrene either developed, or was present, in 12 of these avascular extremities, and three patients died from the infection. This complication was seen largely in patients received late in the hospital, and in those with multiple wounds of the extremity.

Arteriorrhaphy was useful in only a relatively few cases, since its application is limited by the extent of the wound.

Ligation of the artery with its companion vein, prevented secondary hemorrhage, of course, but contributed nothing to the survival of the extremity.

While lumbar sympathetic ganglion block with procaine had no appreciable effect in the majority of patients with severed arteries, it was of value in arterial spasm and should always be a part of treatment.

The results of the Blakemore nonsuture method of blood vessel anastomosis were disappointing, and, although the method has disadvantages which we have pointed out, the poor results may be attributed more properly to the lack of patency of the arterial system distal to the anastomosis.

The conservative management of arterial injuries employed in four patients with popliteal space hematomas cannot be recommended for wide application since the considerable hazard of gas-forming organisms is ever present. We have defined the narrow limits of application in our own series. It should never be employed for the avascular, cold extremity. We justified its use in four selected cases of clean, perforating bullet wounds of the popliteal space, with viable extremities, after having the experience of observing three similar cases result in gangrene after quadruple popliteal vessel ligation.

#### SUMMARY

Loss of some portion of the extremity by gangrene after arterial ligation had the following incidence, at our level of observation in the Forward Areas,

in the arteries studied; axillary, 40 per cent; brachial, 31 per cent; femoral, 82 per cent; popliteal, 77 per cent; all arteries combined, 53 per cent.

For all types of arterial injuries, variously treated, the incidence of resulting impairment of circulation with loss of some portion of the extremity was as follows: Axillary artery, 50 per cent; brachial artery, 37 per cent; femoral artery, 71 per cent; popliteal artery, 67 per cent.

The prognosis for extremity survival in relation to the time factor, arterial wound, extremity wound, anatomic site of arterial injury, and treatment have been discussed.

Six deaths occurred among the 100 patients with injuries of major arteries in the Evacuation Hospital. Infection with gas-forming organisms resulted in 12 patients, of whom three died, accounting for one-half of the deaths in the series.

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# PENETRATING HEAD WOUNDS

## EXPERIENCES FROM THE ITALIAN CAMPAIGN

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DURING THE PAST YEAR of the Italian campaign 140 penetrating wounds of the head, upon whom craniotomy had been performed, were cared for in an Evacuation Hospital. This series of consecutive cases, though essentially similar in their pathology, may roughly be divided into three groups relative of the tactical situation during which they were treated.

Within the period of the Anzio beachhead 53 cases were seen, and all within 24 hours of their injury. Because of the size of the beachhead, distance from the lines to the Evacuation Hospital was short. The patients were all soldiers, and for tactical reasons were evacuated as soon as possible. Chemotherapy consisted entirely of the sulfa drugs.

As the front moved up in Italy from the Garigliano River toward the Gothic Line a second group of 45 cases was treated. The Evacuation Hospital was then well out of range of shell fire and cases reached the hospital somewhat more slowly. There were seven injured civilians in this group. During the latter half of this period penicillin became available for all cases.

The last group of 42 cases was treated when the hospital was situated near the lines but out of range of shell fire. These cases were seen comparatively early and, as with the second group, the tactical situation did not necessitate their evacuation until it was deemed they were well able to travel—in contradistinction to the cases at Anzio. In this last group penicillin as a chemotherapeutic agent was used exclusively. The group was composed entirely of soldiers injured in penetrating and pushing on through the Gothic Line.

An analysis of these three groups forms the subject of this report.

I. *Source of Casualties:* Ninety per cent of all injuries were caused by shell fragments. The large preponderance of these was the result of artillery or mortar fire while a few resulted from fragments of antipersonnel bombs, mines and booby traps. Five per cent of all casualties were gunshot wounds (rifle, machine gun, or pistol). The remaining 5 per cent were attributed to injuries sustained in jeep accidents, falls, a knife wound and the recoil of a breech block.

With the exception of the civilians the age of the patients varied from 18 to 38 years, the mean falling at 24 years. The ages of the civilians ranged from 34 to 56 years.

II. *Evacuation Time:* Table I is included to show the time-interval between injury and surgery. The average time from wounding to surgery was 14 hours at the Anzio beachhead, while 31 hours was the average elapsed time for cases during the Garigliano-Gothic Line phase. If one excluded two cases received eight and 13 days after injury the average in this group is reduced to 21 hours.

III. *Preoperative Findings:* The anatomic location of the various wounds is illustrated in Figure 1.

The most common type of scalp wound seen was a jagged laceration, varying in length from 1 cm. to 12 cm. Almost as frequent were puncture wounds. Occasionally a "through-and-through" injury was encountered in which the more massive damage always occurred at the site of the exit.

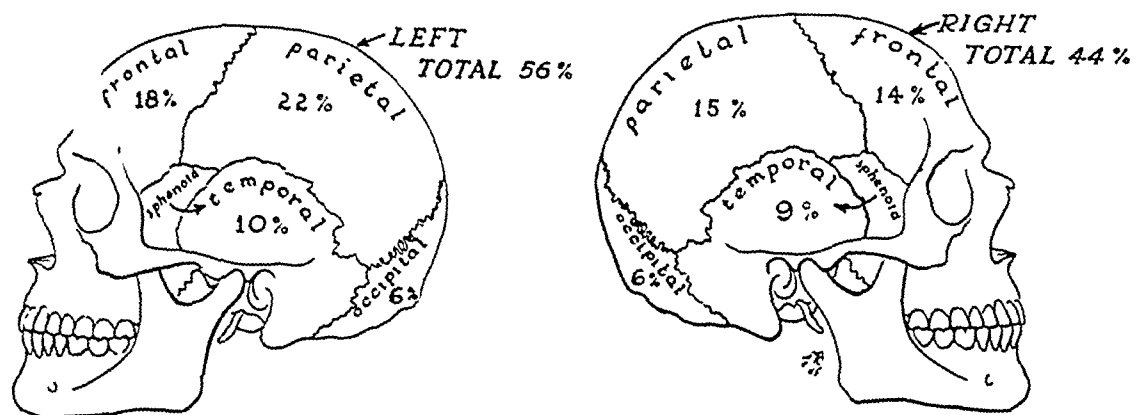


FIG. 1.—Showing the anatomic location of the various wounds.

The exact figure concerning the number of men wounded while wearing their protective helmet is not available. This is partly due to retrograde amnesia caused by the injury and to the fact that the helmet, although worn, was occasionally blown off the head by the shell blast. About half the men claimed to have been wearing their helmets when they were wounded.

Twelve per cent of the patients were admitted in shock. In two-thirds, shock was attributed directly to the head wound while in the other one-third shock was due to associated injuries, particularly of the long bones. Thirty-six per cent of the patients had associated injuries of varying degrees of severity.

Seventy-eight per cent of the patients were conscious at the time of examination. Monoplegia or hemiplegia was found in 20 per cent of all cases, while hemiparesis was noted in 8 per cent. Aphasia was present in 11 per cent of the cases, and 4 per cent had homonymous hemianopsia. More significant was the presence of a decerebrate type of rigidity in 4 per cent of the patients, all of whom died. Half of the 6 per cent of patients incontinent on admission expired. Though the Babinski sign was found in 17 per cent of the cases it seemed to have little prognostic significance.

Almost half of all of these head injuries (43 per cent) had some degree of brain tissue herniating through the wound. Brain hernia was seen only one-fifth as often in puncture wounds as in all other types. Twenty-three per cent of those patients with brain hernia died.

Roentgenograms of the skull revealed intracranial foreign bodies in 53 per cent of the cases, while 43 per cent had indriven bone fragments. Depression of one or both tables of the skull was noted in 49 per cent of cases. Stellate-type fracture was seen in 14 per cent of the cases, and "bursting" fractures were described in 3 per cent. The air sinuses were found to be compounded in 10 per cent of all cases.

IV. *Preoperative Therapy*: Treatment at stations prior to the Evacuation Hospital was largely supportive in character. The patients' wounds were dusted with sulfa powder and a protective head dressing was applied. A stimulating dose of tetanus toxoid was also administered. One-third of the patients required an analgesic and/or sedative, after injury. Morphine, 0.25 gr., was usually administered, being given at the more forward installations. It was seldom necessary to repeat the dose. Half of the patients received plasma, and the average case was given 2.6 units.\* One patient in every five required transfusion of whole blood. The maximum amount of blood given was 2,500 cc., and the average amount was 950 cc.

V. *Anesthesia*: It was possible, with the coöperation of the patient, to carry out the procedure under local anesthesia in 64 per cent of the cases. Procaine, 1 per cent, was used. Sodium pentothal, in conjunction with local anesthesia, was employed in 26 per cent of the patients. This combination had its greatest usefulness in the restless, apprehensive patient, or those upon whom other minor débridements were to be undertaken concomitantly. Gas-oxygen-ether was given to 8 per cent of the cases, and this included the group of major complicating injuries or penetrating head wounds with extensive maxillofacial injury. The remaining 2 per cent of the cases were so deeply comatose that no anesthesia was required.

VI. *Surgery*: The average duration of an operation was one hour and forty minutes. Various aspects of the procedure have been subdivided according to the structures encountered.

(a) *Scalp*.—It was found feasible to effect an elliptical excision of most scalp wounds, since the majority of wounds were roughly linear or were puncture wounds. Where a jagged stellate defect existed only the wound edges were excised, in order to preserve all available tissue for closure. In three instances it was necessary to slide a flap of scalp in order to close the defect, the donor site then being covered with split-thickness skin graft.

(b) *Bone*.—In general, a circular or an ovoid bony defect was encountered. The average circular defect measured 2 cm. in diameter, while the ovoid-shaped defects averaged 2.1 cm. x 4.5 cm. in their narrowest and longest diameters, respectively. Procedure in the usual case was to enlarge the bony defect with rongeurs to obtain clean bone edges and normal dura about the periphery of the defect. By so doing the measurements of the defect were roughly doubled.

Fracture involving the air sinuses, and similarly the orbit, was found in 17 per cent of the cases. The practice of stripping the mucous membrane from the sinus walls was followed out, though in no instance was evidence of sinus infection noted.

(c) *Dura*.—Laceration of the dura was found in 77 per cent of the cases. These dural tears were usually linear in character, and varied in length from 0.5 cm. to 12 cm. Three-fourths of all lacerations averaged 2.3 cm. Multiple dural penetrations occurred in one-sixth of these cases. With more massive

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\* One unit of dried plasma represents the plasma component of 500 cc. of whole human blood.

injuries, dural defects of sizes varying from 2 cm. x 3 cm. up to 5 cm. x 8 cm., were found. Because the dura was rarely found to be grossly contaminated, débridement was confined to excising only the frayed edges of the membrane. In the remaining 23 per cent of cases in which intact dura was found, the membrane was usually tense and less frequently discolored and nonpulsating. Here the dura was opened sufficiently to explore for subdural or intracortical fluid or clot.

Though epidural bleeding was noted in 12 per cent of the cases, in no case was the accumulation felt to be large enough to be of clinical significance. Subdural accumulations of blood or clot were found in a similar frequency, but in half of these cases the volume measured from 40 cc. to 150 cc., and was considered of clinical significance.

Injury to the intracranial venous sinuses and partitioning structures (falx cerebri and tentorium cerebelli) occurred with equal frequency (6 per cent of the cases).

(d) *Brain*.—The paths of most foreign bodies and/or bone fragments through the cortical substance created tracts which usually were roughly cylindrical in shape, though some were conical and fewer were shallow craters of the brain substance. Tracts varied in length from 2 cm. to 17 cm., the average being 8.1 cm. Aspiration, by suction and irrigation, of the pulped cortical tissue and clots found along the tract produced a tunnel through the brain along the sides of which was found a thrombosed plexus of cortical vessels, apparently the supporting vascular frame work for that area of the brain prior to injury. Where a foreign body and bone fragments were found intracortically the foreign body was always at the deepest portion of the tract. An effort was made to dislodge both bone fragments and foreign bodies by irrigation or under direct vision. In narrow or deep tracts where metallic foreign bodies could not be visualized, their removal was attempted by gently contacting them with a magnet. This was successful in about half of the cases. Where feasible, finger exploration of the débrided brain tract was undertaken, frequently revealing retained bone fragments or pockets of incompletely débrided soft brain tissue.

As has been noted, there was roentgenographic evidence of intracranial foreign body in 53 per cent of all cases. Sixty per cent of these were removed surgically. On the other hand, roentgenograms revealed evidence of indriven bone fragments in 43 per cent of all cases, but bone chips were removed from the brain in 57 per cent of all cases.

Seventy-nine per cent of all tracts were unilateral, and 21 per cent were bilateral. Tracts crossing the midline were found to be twice as fatal as others. The ventricular system was found to have been compounded in 20 per cent of the cases, and of these 35 per cent terminated fatally.

(e) *Repair*.—In the group of cases operated upon at the Anzio beachhead it was generally the policy to introduce sulfa powder into the wound. This was sprinkled lightly into the brain tract in three-fifths of the cases and along the scalp wound in another fifth. This practice was discontinued in the subse-

quent group of cases and no local chemotherapy was used until penicillin became available. In roughly the last half of the cases of the entire series, 10,000 units of penicillin in 2 cc.-5 cc. of distilled water was introduced into the brain cavity.

Tight primary closure of the dural wound was possible in over half of all cases. In an additional 7 per cent of cases a tight closure was effected through the employment of grafts, using either pericranium or fascia lata. This procedure was thought imperative in compound wounds of the ventricles. In

TABLE I  
TIME-INTERVAL BETWEEN INJURY AND SURGERY

Time-interval	Anzio	Garigliano-Gothic Line
0-4 hours.....	2	0
4-8 hours.....	7	6
8-12 hours.....	13	8
12-18 hours.....	14	11
18-24 hours.....	10	6
24-48 hours.....	5	7
Unknown.....	2	
Over 2 days.....		2
Over 3 days.....		2
Over 4 days.....		1
Over 8 days.....		1
Over 13 days....		1

30 per cent of the dural wounds the edges could be approximated but no tight closure secured. In the remaining 12 per cent of the cases no closure was attempted. This includes a small number of cases in which a subtemporal decompression was left, or where surgically inaccessible lacerations were bridged by adjacent structures. For example, linear tears of the inferior surface of the frontal lobes were frequently associated with comminution of the superior plate of the orbit and laceration of the periosteum of the orbit. Here, herniation of the retro-orbital fat against the torn dural edges seemed to effect a satisfactory closure.

Two-layer scalp closure was undertaken except in those occasional cases where, due to the precarious state of the patient, a single-layer scalp closure was made to save time. In 60 per cent of the first group of cases a small Penrose drain down to the dura was placed for a 24-hour period. This practice was discontinued in the latter two groups of the series.

VII. *Postoperative Treatment*: The first half of the patients in this series received sulfathiazole or sulfadiazine as a postoperative routine. When penicillin became available this regimen was discontinued. The patients in the second half of the series got 25,000 units of penicillin intramuscularly every three hours for at least five days. Lumbar puncture, blood and plasma were used when deemed necessary. Patients were given fluids and food by mouth and encouraged to become ambulatory as soon as possible. Though it was necessary, for tactical reasons, to evacuate the average patient in the Anzio group on the fourth postoperative day, cases in the latter two groups could be held for a week or longer before being sent back to Base Installations.

# PENETRATING HEAD WOUNDS

TABLE II.—SUMMARY OF DATA IN 24 FATALITIES.

1	2	3	4	5	6	7	8	9	10
NO.	REG- ION INV- VOLV- ED*	ADD- TIONAL IN- JURY	TIME- HRS. INJ- SURG	NEUROLOGIC FINDINGS	CROSS MID LINE	COM- P'D. VEN- TRI- CLE	POSTOPERATIVE COURSE	DAY DIED POST- OP.	AUTOPSY
1	R.O.	ABD., CHEST	7	NEGATIVE, CONSCIOUS	0	+	HYPERTHERMIA	3	BASAL SOFTENING ABOUT TRACT
2	L.F.	EYE	15	CONSCIOUS — B.P. 160/80	+	0	INCREASING HYPERTENSION, HYPERTHERMIA	1	DIENCEPHALIC PETECHIAE, BLAST INJURY OF LUNGS, KIDNEY.
3	R.F.P	0	9	COMA; HYPERPNEA; RT. EXTENSOR RIGIDITY; IN- CONJUGATE E.O.M.; INCONT.	0	0	DECEREBRATE RIGIDITY	3	NO TIME TO DO AUTOPSY
4	L.F.P	0	31	COMA; L. HEMIPLEGIA; HYPER- PNEA; INCONTINENT; BILAT. BABINSKI; INTERMITTENT SPASM	0	+	DECEREBRATE RIGIDITY HYPERTHERMIA	3	NO TIME TO DO AUTOPSY
5	L.T	0	35	COMA; INCONTINENT; RESPIR- STERTOR; DECEREB. RIGIDITY BILATERAL BABINSKI	+	0	DEEP COMA INCONTINENT	2	PETECHIAE ABOUT TRACT, MULTIPLE CONTUSIONS
6	L.P.	0	12	COMA; PULSE 150; BILAT. HY- PERREFLEXIA & TONICITY; RIGHT BABINSKI	0	0	HYPERPNEA HYPERTHERMIA	1/2	BASAL NUCLEAR SOFTEN- INGS AND PETECHIAE
7	L.F.	MULTIPLE PEN. WOUNDS COLOSTOMY FCC FEMUR	22	DROWSY; OTHERWISE NEURO. NEGATIVE	0	0	DOING WELL UNTIL DIED SUDDENLY	7	SMALL SOFTENINGS ABOUT TRACT; INSUFFICIENT TO CAUSE DEATH; REASON OBSCURE.
8	R.SUB OCCIP.	FCC HUM- ERUS WOUNDS OF THIGH	13	DROWSY; PROJECTILE VOMITING; NEURO. NEG.	+	+	IRRATIONAL EXPIRED SUDDENLY	1	SOFTENING, LACERATION OF CEREBELLAR LOBES. INTERNAL HYDROCEPHALUS
9	L.P.	MAL- ARIA	12	COMA; STERTOR; RESPIRATION L. HEMIPLEGIA; BABINSKI L. HOFFMAN; DILATED FIXED PUPILS	0	0	RAPIDLY DOWNHILL	1	DIFFUSE SUBDURAL & SUBARACH. HEMORRHAGE; MULTIPLE PETE- CHIAE MESENCEPHALON
10	R.O.P	HEAD WOUND, INFECTED ON ADMN	80	SEMICOMATOSE; RESTLESS; WOUND PURULENT	0	0	REMAINED COMATOSE	2	INFECTION LOCALIZED EXTRA- DURALLY; CEREBRAL SOFTENING MESENCEPHALIC HEMORRHAGE
11	R.T.P	HEAD & ARMS INFECTED ON ADMN	96	COMA; SHOCK; TOXIC DEHYDRATED	+	+	RAPIDLY DOWNHILL PENICILLIN	1/2	ACUTE FULMINATING CEREBRITIS; MENINGITIS
12	L.T	LAC. WD ARMS	8	COMA; HYPERACTIVE LEFT DEEP REFLEXES; BABINSKI LEFT HEMIPLEGIA	+	+	DROWSY; HYPERPNEA HYPERTHERMIA.	3	SOFTENING (BASAL) ALONG TRACT
13	R.T.P	0	12	DEEP COMA; BLOOD IN RT. EXT. EAR; L. BABINSKI; ECCHY- MOSIS OF RIGHT EYE	0	0	COMA; HYPERPNEA HYPERTHERMIA	1	CORTICAL CONTUSION, EXTENSIVE SKULL FRACTURE, SUBARACHNOID HEMORRHAGE
14	L.T.	0	9	COMA; LT. ANKLE CLONUS SPASTIC QUADRIPLEGIA BILAT. BABINSKI	+	0	COMA HYPERTHERMIA	1	AUTOPSY NOT DONE
15	L.P	SHOCK	6	RT. HEMIPLEGIA; HYPERPNEA, RT AREFLEXIA	0	+	REMAINED COMA, HYPERTHERMIA	3	AUTOPSY NOT DONE
16	R.F.T.	0	10	COMA LT. HEMIPLEGIA	0	+	HYPERPNEA HYPERTHERMIA	1	AUTOPSY NOT DONE
17	L.T.	SHOCK	54	COMA; CHEYNE-STOKES BILATERAL BABINSKI DECEREBRATE RIGIDITY	0	0	HYPERPNEA HYPERTHERMIA	3	MULTIPLE PETECHIAL HEM. BASAL SOFTENINGS HEMORRHAGE
18	L.P	0	12	DEEP COMA, STERTOROUS RESP; HYPERTHERMIA	0	+	CONTINUED COMATOSE	1	EXTENSIVE CEREBRAL THROMBOSIS ABOUT TRACT
19	R.P	0	14	COMA; VOMITING; RIGHT HEMIPLEGIA LEFT BABINSKI	0	0	RESPONDED TO SURGERY—LATER COMA & HYPERPNEA	3	ENCEPHALOMALACIA, PARIETAL LOBE, LEFT, WITH CORTICAL LACERATION & HEMORRHAGE
20	L.T	0	3	IRREGULAR RESP, COMA; BILATERAL ATONIA FIXED PUPILS	+	0	PULSE BECAME IMPERCEPTIBLE AT SURGERY	1/2	BASAL SKULL FRACTURE; SUBARACH- NOID HEM; BASAL CISTERN PETE- CHIAE, DIEN. & MESENCEPHALON
21	L.T	MULT PEN. WDS	15	SEMICOMA; SHOCK; APHASIA RT. HEMIPLEGIA, BABINSKI	0	+	COMA; HYPERPNEA HYPERTHERMIA	1	AUTOPSY NOT DONE
22	L.P.	0	27	SEMICOMA; IRRITABLE; IN- VOLUNTARY; MODERATE BILAT EXT'R. RIGIDITY; BILAT. BABINSKI	+	+	COMATOSE HYPERTHERMIA	2	BILAT. ENCEPHALOMALACIA OF PARIETAL LOBES ABOUT TRACT.
23	L.F.	PEN. WDS. ABD. LEGS	24	SEMICOMA; APHASIA RT. HEMIPLEGIA	+	+	DEVELOPED INT. HYDROCEPHALUS	3	BLEEDING INTO BASAL CISTERN CLOT IN AQUEDUCT OF SYLVIVS PETECHIAE ABOUT TRACT
24	L.P	0	12	COMA; RT. BABINSKI; HEMI- PLEGIA; HYPERTONIA AND HYPERREFLEXIA	0	+	DID NOT RESPOND HYPERTHERMIA HYPERPNEA	3	BASAL SKULL FRACTURE; INTRA- VENTRICULAR BLEEDING; PETE- CHIAL L. FRONT. & TEMP. LOBES

\* KEY: R—right; L—left; P—parietal; O—occipital; T—temporal; F—frontal

TABLE III.—BRIEF ANALYSIS OF 16 CASES IN WHOM INFECTION WAS PRESENT.

HOURS INJ. TO SURG.	INFECTED ON AD- MISSION	COM- POUND SINUS, EAR, ETC.	FOREIGN BODY PRESENT	FOREIGN BODY REMOVED	BONE FRAG- MENT PRESENT	BONE FRAG- MENT REMOVED	DURAL REPAIR	DRAIN TO DURA	CHEMOTHERAPY			INFECTIONS	RESULT
									TRACT	SCALP	SYS- TEM- IC		
29	0	0	0	0	+	+	FASCIA LATA GRAFT	+	0	+	S	BRAIN ABSCESS	IMPROVED
26	0	0	0	0	0	0	CLOSED	0	0	+	S	SCALP ONLY	WELL
14	0	0	+	+	+	+	APPROX.	+	+	0	S	ABSCESS, MENINGITIS	DIED
15	0	0	0	0	+	+	APPROX	+	+	+	S	SMALL ABSCESS	WELL
27	0	0	+	+	+	+	CLOSED	+	+	0	S	SCALP ONLY	WELL
24	0	EXTERNAL EAR	+	0	0	0	NOT CLOSED (DECOMP)	0	+	0	S	ABSCESS	DIED
18	0	0	0	0	+	+	CLOSED	+	+	0	S	ABSCESS	IMPROVED
8	0	FRONTAL SINUS, ORBIT	0	0	+	+	CLOSED	+	+	0	S	CEREBRITIS, ABSCESS	UNIM- PROVED
80	CELLULITIS OF SCALP, OSTEO OF SKULL	0	0	0	0	0	INTACT & PURULENT EXUDATE	WOUND PACKED OPEN	0	PENI- CILLIN	P	INFECTION LOCALIZED EXTRADURALLY	DIED— NEUROGENIC DEATH
96	FULMINATING CEREBRITIS	0	+	0	+	0	WOUND PACKED OPEN	0	+	0	P	FULMINATING CEREBRITIS & MENINGITIS	DIED
24	0	0	0	0	+	+	CLOSED	+	0	0	P	SCALP ONLY	WELL
200	CELLULITIS SCALP LOCAL OSTEO OF SKULL THICK INF. DURA	0	0	0	0	0	INTACT	WOUND PACKED OPEN	0	PENI- CILLIN	P	INFECTION LOCALIZED EXTRADURALLY	IMPROVED
19	0	MASTOID CELLS	0	0	+	+	CLOSED	0	0	0	P	SMALL ABSCESS	IMPROVED
320	LOCALIZED DRAINING BRAB- SCS, OSTEO	FRONTAL SINUS	0	0	+	+	LEFT OPEN	WOUND PACKED OPEN	PENICILLIN WICK	0	P	LOCALIZED DRAINING BRAIN ABSCESS	IMPROVED
17	0	0	+	+	+	+	CLOSED	0	+	0	P	BRAIN ABSCESS	IMPROVED
20	0	0	+	+	+	+	CLOSED	0	+	0	P	CEREBRITIS, MILD— DID NOT REQUIRE SURGERY	WELL

## PENETRATING HEAD WOUNDS

VIII. *Deaths*: There were 24 fatalities in this series, a mortality of 17 per cent. Analysis of these deaths appears in Table II.

IX. *Disposition*: Of the 116 patients evacuated from this hospital all were sent to General Hospitals in the rear, except for seven Italian civilians who were placed in civilian hospitals. These civilians were held at our hospital until such periods in their convalescence that we felt they were past the hazard of infection, since civilian hospitals at this time were frequently not equipped to undertake neurosurgery. In the group of 109 military patients it was possible to obtain follow-up data on 103. Records of the other six cases are still incomplete. Of the followed cases, 16 per cent were returned to duty, while 84 per cent were sent to the Zone of Interior (United States) after varying periods of recovery in Base Section General Hospitals. The most pertinent problems in this followed group seemed to be those of infection and the necessity of reoperation. Full neurologic recovery had not been made by most patients. Table III is a brief analysis of the 16 patients in whom infection was present. These are listed chronologically. Discussion of this data is reserved for a later section of this paper.

It was found necessary to perform a secondary craniotomy upon 18 patients at General Hospitals. Eight of these patients had brain abscesses. Table IV is a summary of these secondary operations performed for residual non-infectious disease.

COMMENT: The Evacuation Hospital is the unit in the Italian campaign where the large majority of penetrating head wounds underwent definitive surgery. When a great influx of casualties occurred it was found necessary to establish some system of priority for surgery. It soon became evident that certain patients with head wounds would probably not survive intervention. In this category were those in deep coma, with stertorous breathing, a rapid pulse, and low blood pressure, and who exhibited such neurologic signs as decerebrate-type of rigidity, fixed unequal pupils and involuntary micturition. Because they tended to develop pulmonary edema, frequent aspiration of the pharynx and trachea was necessary. They were given whole blood and concentrated solutions of plasma but usually continued to go downhill. Less severely wounded men usually improved after such a regimen. It was the patient who, despite a rapid pulse, initially low blood pressure, and marked neurologic signs, tended to improve that we felt warranted priority surgery. In none of these cases, however, was surgery undertaken as an emergency measure. Though it was occasionally necessary to control a scalp bleeder with a clamp or a ligature, it was thought that patients generally withstood surgery better if given adequate opportunity for stabilization of their vital signs.

It is curious to note that 12 per cent more injuries occurred on the left rather than the right side of the head. This ratio has remained constant through the various groups comprising the entire series. One can only speculate as to an explanation. It is conceivable that since soldiers are predominantly right-handed, they are somewhat more alert to danger on their right. Likewise, one can but theorize as to the value of the protective helmet from these statistics. Assuming equal protection over the head, the fact that



the temporal and occipital regions are less frequently wounded could be explained by their relatively smaller surface area but, more significantly, more basal injuries are most lethal and probably never reach the Evacuation Hospital.

TABLE IV

SUMMARY OF DATA UPON 18 CASES REQUIRING SECONDARY CRANIOTOMY FOR RESIDUAL NONINFECTIOUS DISEASE

Preoperative Diagnosis	Findings	Result
1. Intracortical hematoma	Soft brain, clot along tract	Improved
2. Intracortical mass lesion	Subdural hematoma; softening along tract	Improved
3. Intraventricular bone fragments	Fragments removed; noninfected	Well
4. Subdural hematoma?	Negative exploration	Improving
5. Brain fungus	Fungus resected; primary closure	Well
6. Intracranial mass lesion	Bilateral subdural hematoma (missed on primary exploration for hematoma)	Improved
7. Subdural hematoma?	Small epidural hematoma	Well
8. Intracortical foreign body	Foreign body not found	Unimproved
9. Intracranial mass lesion	Intracortical hematoma	Improved
10. C.S.F. rhinorrhea	Repair of dural tear	Well

Because one in three patients exhibits some measure of paralysis, aphasia or hemianopsia, a philosophy of adequate but not necessarily radical débridement was adopted. Devitalized, contaminated bone was resected, but not "*en bloc*." Every effort was made to remove all bone fragments and pulped brain tissue from the tract because of their known tendency to produce abscesses. Small shell fragments, on the other hand, were frequently left *in situ* since they were much less likely to harbor infection. Surgically inaccessible lesions, previously referred to, should be construed as those whose repair might require more extensive surgery than the nature of the lesion itself would justify. This principle is equally applicable to certain deeply situated small shell fragments.

Of the 103 soldiers on whom follow-up data was available 11.6 per cent subsequently developed some form of infection. It may be of interest to examine more closely the various factors which might explain the difference between an incidence of 21 per cent infection of the cases operated upon on the Anzio beachhead and 5.7 per cent of the cases resulting from the Gothic Line push. The time-interval between wounding and surgery was slightly longer in these infected cases. The fact that a missile traversed the air sinuses, orbit, external ear or mastoid cells on its path into the cranium did not seem to enhance the likelihood of any particular case becoming infected. Likewise, a metallic foreign body left *in situ* did not seem to increase the incidence of sepsis. Bone fragments are seen less frequently roentgenographically than they are found surgically. It is, therefore, not unlikely that other smaller fragments are missed at operation. In several instances small fragments, missed at primary débridement, were later found when a brain abscess was drained. On the other hand, retained bone fragments were the indication for secondary craniotomy in another case, and were noninfected when removed from the wall of the lateral ventricle. For this reason, whether they act as a nidus of infection cannot be definitely ascertained in any particular case. There seems to be no relation between the type of dural repair and likelihood

## PENETRATING HEAD WOUNDS

of subsequent sepsis. In 60 per cent of the cases operated upon at Anzio a small Penrose drain was placed down to the dura. One in five of these patients developed infection. It became evident when these cases were seen in General Hospitals several months later that the use of the drain did not prevent infection and may have contributed to it. Its use was discontinued except in the occasional case.

As has been stated, during the phase of the Anzio beachhead the sulfa drugs were used chemotherapeutically, whereas only penicillin was used in the most recent (Gothic Line) phase. There were almost four times as many infections in the former group. Any improvement, however, cannot be directly attributable to a change in chemotherapy alone, since the practice of draining was discontinued and because, for tactical reasons, it was possible to hold this latter group until wound healing was more complete before evacuation.

A mortality of 17 per cent has characterized all groups of the entire series. This would seem to vary almost directly with the tactical situation. When time is not a factor there is a tendency to attempt surgery upon patients whom one feels may have been doomed since wounding. During a great influx of patients priority must be given to those who have a reasonable chance to survive. Time was not always available to perform postmortem examination. On gross examination of 18 brains removed at autopsy, death was due directly to the effects of brain injury, except for one case who died of a fulminating cerebritis present on admission.

### SUMMARY

A consecutive series of 140 cases of penetrating wounds of the head sustained during the past year of the Italian campaign is presented. Craniotomy was performed upon these patients at an Evacuation Hospital. Thorough but not extensive débridement was attempted. Penicillin seemed more efficacious as a chemotherapeutic agent than the sulfa drugs in this series.

# TREATMENT OF JAW AND FACE CASUALTIES IN THE BRITISH ARMY

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THIS ACCOUNT of the treatment and results of 1,000-jaw casualties\* is made with special reference to the fixation of the bone fragments and the early repair of the soft tissues. An attempt is made to compare the methods of treatment in British and American Armies. The work was done in North Africa and Italy. In both countries this Unit came in frequent contact with the maxillofacial services of the United States and of the French Armies. The Unit landed in North Africa with the First Army in November, 1942. In the early part of the Tunisian Campaign it shared in the early treatment of American as well as British casualties. Subsequently, in Italy, it had the late care of many British casualties who had had their primary treatment in American hospitals.

In North Africa all British M. F. casualties were concentrated in the one Center at Algiers. The early treatment was done by Forward general surgeons, as was the case with the Eighth Army M. F. casualties in the Desert campaigns. The policy of concentrating all M. F. cases was extended in Italy where, at Naples, this Unit was responsible for the treatment of the British M. F. casualties from the battles and combined operations on the west coast. Working in the facilities of a General Hospital 50 miles from a static Front, it was able to develop the surgery of the soft tissues and in particular to explore the scope of primary suture in battle wounds of the face. After Cassino, when the Armies advanced along the peninsula, the system of concentrating M. F. casualties into one Forward Unit continued. The Unit provided a Forward Section which was equipped to do full facial repairs, and was able to hold its cases for three to five days before evacuating them by air to its own Main Section at Naples. This Forward Section was placed together with Special Head and Special Eye Units, at a Forward Hospital, or C. C. S., so that casualties reached it in six to 30 hours. A most successful system of *triage* assured that all British head, eye, face and jaw (and most pharyngeal) wounds arrived at the Forward Hospital to which these three special units were attached. This system, rather than the alternative of having individual specialists attached to general units, was a success because: the early forward sorting was very efficient; special equipment in generous

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\* Cases treated up to November, 1944.

quantities had been concentrated at these special units; and distribution of personnel and equipment between Forward and Main Sections of the Maxillofacial Unit was left a Unit responsibility by higher administration; it was thus possible for changes to be made easily and quickly to meet the varying demands of the two Sections.

The work of the Main Section at Base has been the intermediate care and the late repairs. The number and extent of late repairs has depended on the number of hospital ships and on the pressure of work. In practice, nearly every case has been held one to two months; many whose total period of incapacity has been four to seven months have been seen through to union of the jaw, correction of their facial deformity, and return to duty in the Mediterranean. Of 1,000 jaw fractures\* described here, 600 returned to duty in the Mediterranean; 400 were evacuated to the United Kingdom healed after one to two months treatment at Main Section of the Unit.

Split into Forward and Main Sections a single M. F. Unit has the opportunity—rare in the Army—of being able to follow its cases through from Forward surgery to return to duty, and of being able to correlate both aspects, early and late, of military M. F. work.

*The Maxillofacial Casualty.*—This paper is concerned only with the casualty who has a jaw fracture. Seven hundred of the 1,000 cases were missile wounds. Forty per cent of these were due to mortar; nearly 30 per cent each to shell and bullet and less than 5 per cent each to grenade mine and bomb. These 700 missile wounds include 50 each of associated major pharynx and palate wounds.

Three hundred cases were closed injuries and were chiefly caused by vehicle accidents including battle accidents; a third of the closed injuries were due to brawls.

A typical missile fracture of the jaw shows gross comminution with involvement of an indeterminate number of teeth and scattering of bone and tooth fragments into surrounding soft tissues. The track of the missile commonly penetrates tongue and pharynx and may lead towards the cervical spine across the carotid sheath.

The missile which traverses the maxillary block often destroys the eye and disorganizes antrum and palate. If it is a large missile the whole block may be "floating" with gross malocclusion, and comminution may involve ethmoid and sphenoidal sinuses and the floor of the anterior cranial fossa. There is a high incidence of associated brain injury, and death from this and from respiratory complication is relatively common compared to mandibular wounds.

#### TREATMENT OF THE MAXILLOFACIAL CASUALTY

Treatment of the maxillofacial casualty falls into three phases: early, intermediate, and late. The less that is done at the primary treatment the more extensive and prolonged are the intermediate and late phases.

For the greater part of this war the early treatment of maxillofacial

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\* In 4,600 casualties (maxillofacial, burns, and body plastics) treated in 2.5 years.

casualties in the British Army consisted chiefly of dental fixation. Repair of soft tissues was left until after natural healing, with deformity. This treatment led to prolonged hospitalization for even minor facial wounds. Conservation of dead bone and soft tissues caused a high incidence of infective complications. The treatment described here has been the routine for the casualties in Italy. It was evolved as a result of experience in North Africa, when ample opportunity of seeing the results of conservative early surgery was afforded the Unit in Algiers.

#### EARLY TREATMENT

1. *Soft Tissues.*—A primary closure of a face wound is more often possible and safe than it is in most other sites. The tracks of many of the missiles



FIG 1.—Primary soft tissue repair of major mandibular wound with gross bone loss

A Disruptive wound six hours old

B The same after clearance of bone fragments, soft tissue excision and closure The drain was out and healing complete at ten days

are capable of thorough excision, and the free blood supply ensures a maximum survival of damaged tissues. The surgeon must be certain that he can hold his cases three to five days and supervise removal of his own sutures. Under the right conditions primary closures not only shorten healing times drastically, to the great relief of the patients, but diminish the incidence of bone infection. Whenever possible the jaw should be fixed at the same operation. If splints have to be used it is usually wise to accept the six to eight hours delay necessary for their construction. About 20–30 per cent of maxillofacial missile wounds are suitable for primary final repairs.

These primary repairs are done when the wound looks clean, is under 24-36 hours old, and the tissue loss is such that repair from local tissue is possible. There is a meticulous removal of all dead tissue, careful minimal skin excision with production of a nonbevelled edge; and the best cosmetic closure done that is possible without prejudice to any late repair that may be necessary. Minor degrees of skin loss are made up by undermining, which may be of the order of 1 to 5 cm. Major flaps have seldom been used in primary repairs. Over some traumatic antrostomies with gross loss of skin, a bed of subcutaneous tissue has been fashioned, and then covered by thin split-skin graft. Primary free grafts to the face nearly always need a later cosmetic repair. Mucocutaneous suture has only been done when the tissue loss has been too great to permit primary reconstruction; the same meticulous surgery of bone and soft tissue which are closed must be done as in a primary skin closure. Whenever possible fistulae are closed at the initial operation, using mucosal flaps if necessary.

Parenteral penicillin has been used early in a number of cases. It cannot control infection in a fracture site which involves teeth and communicates with the mouth, and no decrease in bony infective complications has been noted in such cases. But in cases of early closure of facial wounds including those involving bone local penicillin reduces the incidence of suture line infection; systemic penicillin produces even quieter healing. But the general scope of early closure of facial wounds is not materially increased by penicillin.

Hemorrhage in an M. F. wound is almost always controllable by local attack on the bleeding point through the wound. We have never found it necessary to do a primary proximal arterial ligation and only very exceptionally have had to enlarge a wound to obtain access to the bleeder.

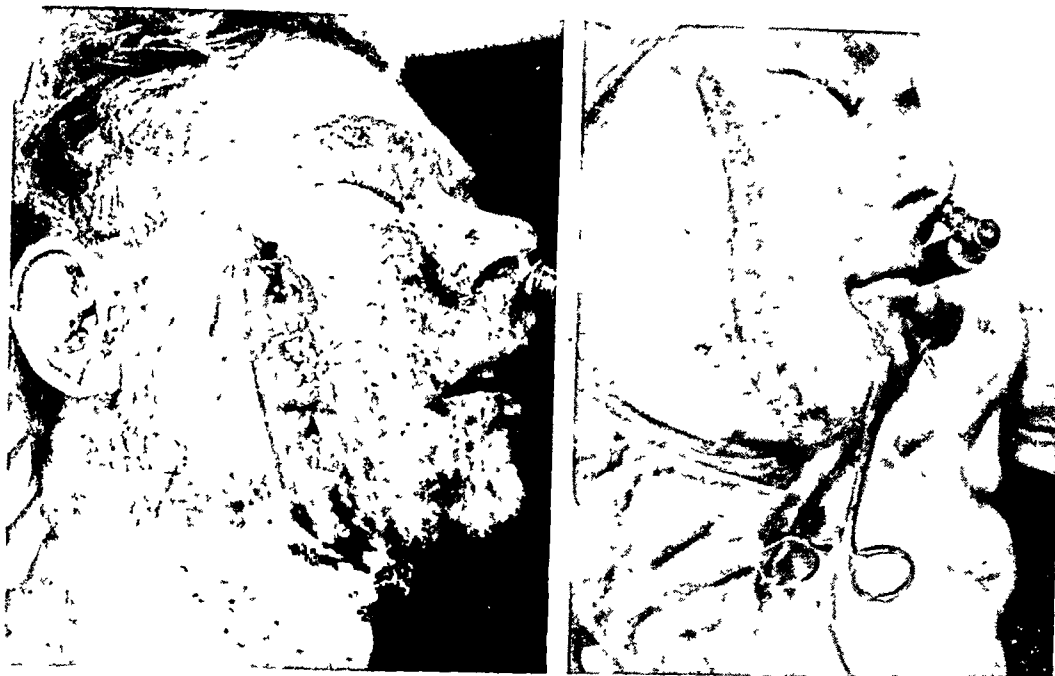
2. *Wounds of the Pharynx*.—There is a considerable difference in prognosis and in treatment between wounds of the naso- and oropharynx and those of the laryngeal part.

The upper pharyngeal wounds of this series were caused by missiles passing through antrum or ascending ramus. A thorough track toilet by finger or forceps is sufficient; repairs by either external or internal approaches are neither practicable nor necessary. Uneventful healing is the rule, except when the cervical vertebrae are involved and are comminuted. In this series of 50 pharyngeal wounds there were four cases of osteomyelitis of the spine which caused an internal pharyngeal fistula to persist.

The risks of serious infection from wounds of the lower pharynx are much greater, and probably derived from the seepage of saliva and of discharge from the fracture site into them. In wounds of the laryngeal pharynx, if there is evidence of early infection, it is often wise to convert an internal wound into an external pharyngotomy by a deliberate exposure to establish dependent drainage. But in a number of favorable early cases a full exposure of the pharyngeal hole, with excision of the track and com-

A

B



C

FIG. 2 — Primary repair of major combined mandibular and maxillary wound.

A. Mine wound of face eight hours old, with combined fractures of mandible and maxilla and an external traumatic antrostomy. The mandible was diffusely comminuted for 1 cm. in 345 region, and the roots of these teeth were fragmented.

B. A minimal but meticulous excision of all layers of the wound has been done. Comminuted displaced antral and mandibular fragments have been removed. A water tight closure of the mouth has been effected by mucosal flaps. Involved teeth have been extracted, and the jaw fragments fixed with eyelet and direct wires, after impressions had been taken for future cast metal splints.

A thorough soap and water toilet of the face has removed most of the ingrained mud. A skin closure with fine interrupted suture silk completed the operation.

C. The patient ten days later.

There was primary union of the whole wound by the third day, when the remaining sutures were removed. Wire fixation was changed for cast metal splints at the end of the second week.

plete closure in layers, has been successful. A tracheotomy has been done at the same operation as primary pharyngeal closure.

3. *The Comminuted Mandible*.—Our policy has been to remove, early, all detached or infected bone, but to conserve all bone that may survive, except when a bone-gap is already present; a complete bone clearance is then done and leads to healing in a few days. Incomplete fractures are mostly best treated by a radical clearance, and closure.

Prophylactic dependent drainage of nonsuppurating mandibular fractures has not been our practice, as it delays healing time and can infect the bone.

4. *Wounds of the Antrum*.—Wounds of the antrum provide a favorable field for radical surgery and early closure. Soft tissues of the wound and track are treated by meticulous and thorough excision. Healthy intact antral and nasal mucosa is left. A good nasal antrostomy is established when the missile has not already done this. Comminuted antral wall and all maxillary fragments having no structural value are cleared out; but major alveolar fragments and orbital floor are treated with great conservatism. This radical policy with comminuted antral fragments is adopted because when these fragments are left, progressive sequestration and long-standing antral infection is the rule.

Soft tissues are closed in layers over the traumatic antrostomy. Considerable undermining may be necessary for a closure without pulling on lids or lips. Only one antrum out of a series of 40 antral closures became infected—a man who had pus in his antrum at the time of injury; the closure healed by first intention. Buccal or antral fistulae are closed whenever feasible; for these fistulae a one-layer closure by a large single flap of buccal mucosa has often been used successfully.

Hemorrhage in antral wounds is seldom troublesome at operation, and is nearly always controllable by hot packs. In one case the internal maxillary artery had to be secured through a hole in the posterior wall of the antrum.

5. *Fixation*.—A missile fracture of the jaw is best fixed within two days of injury except when: 1. There is an associated wound of tongue and pharynx with so much swelling that suffocation is likely to occur if jaws are fixed together; and 2, when nasal obstruction is present—usually fractures of maxillary block with some associated head injury—and there is a similar danger of suffocation. Intermaxillary fixation (I. M. F.) is best delayed in these cases for about a week, and whenever possible should then be done without an anesthetic.

TABLE I

SHOWING DENTAL FIXATION INSTITUTED AT THE UNIT

Cases treated by cast metal splints.....	397
Cast metal splints fitted.....	847
Cases treated by dental wiring (eyelets, direct, all types).....	500
Cases treated by per alveolar and circumferential wire.....	45
Cases treated by interosseous wiring.....	15
Cases treated by Rodger Anderson extra-oral pins.....	15
Cases treated by P.O.P. headcap C.M.S. and external rods.....	38



*Wire Fixation.*—A large majority of all jaw fractures can be satisfactorily treated throughout by wire; and in the first instance wiring is best for nearly all missile injuries. It is a quick method in expert hands, and can keep up with a high intake of casualties. Eyelet wiring, which we consider quicker to apply than continuous wiring, has been the most widely used method. It requires close supervision and the maintenance of 60 cases treated by wire will fully occupy one dental specialist.

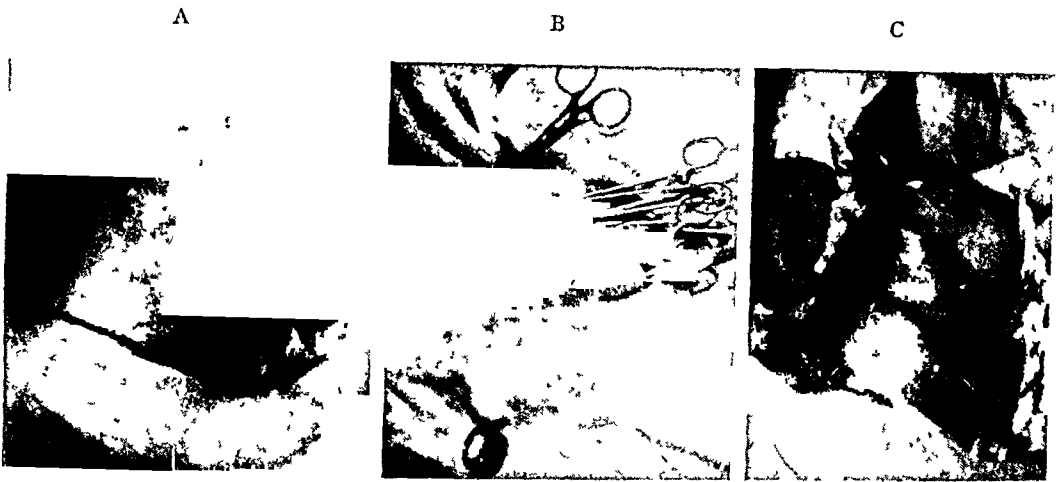


FIG. 3.—Primary repair of pharynx wound:

A. Eight-hours-old T. and T. wound comminuting lower border of right side of symphysis and passing down through left pyriform fossa and left side of laryngopharynx to emerge in front of middle of sternomastoid.

B. T. and T. wounds connected, whole tract excised and bone fragments cleared out. The dissecting forceps are being held in the pharyngeal rent.

C. Closure in layers, with drain down to pharyngeal wall. Healing was complete in ten days at which time he was eating a normal diet.

We have used wire intermaxillary fixation (I. M. F.) in preference to elastics as we believe that wire I. M. F. is firmer and better, but we have seen many cases successfully treated by elastic I. M. F. at American hospitals, and there is no doubt that both methods give good results. Elastics have been reserved by us for cases needing gradual reduction, and have been found of value.

The caliber of wire most satisfactory for general use has been 0.5 mm. stainless steel wire for the eyelets and double thickness 0.35 mm. stainless steel wire for I. M. F. Three pairs of eyelets are usually enough; but in multiple fractures up to six pairs have been used.

Some cases of scanty dentition, unusual occlusion, and some multiple fractures cannot be fixed by wire. For this minority early splints are necessary.

6. *Air-way.*—It is sound practice in military surgery to do a tracheotomy on any M. F. casualty with distress from upper respiratory obstruction which is not relieved by a simple mechanical toilet of the mouth, nose and pharynx, especially under busy conditions or when evacuation is unavoidable.

It should be done when I. M. F. is necessary in the presence of gross intra-oral damage or nasal obstruction; in most cases of primary closure of

## JAW AND FACE CASUALTIES

wounds of larynx and pharynx; in emergency, for any acute upper respiratory obstruction if an endotracheal tube cannot be passed.

In all these cases a transthyroid tracheotomy is probably best, as the tube

A



B

FIG. 4.—Primary repair of antral wound:

A. Disruptive 40-hours-old wound causing destruction of orbital contents floor, lower lid and surrounding cheek, with gross traumatic external antrostomy.

B. The same four days after radical débridement of antral wall fragments and closure of antrostomy by up-turned subcutaneous flap covered with a thin split-skin graft.

is generally required for several days. Laryngotomy is reserved for cases of the most extreme urgency. Only one laryngotomy was done in this series.

It is probably true to say that too few rather than too many tracheotomies are done in Forward areas. Twenty-seven of these 1,000 cases had a tracheotomy. In one there was a serious complication (erosion of the

innominate by a low tracheotomy tube). In none of the others were there any adverse effects attributable to the tube, though it was often retained for one to three weeks during repeated evacuations.

7. *The Teeth*.—For the shell wounds of the jaw an early conservative policy with teeth is wise. Loose teeth and those easy to remove are extracted but many teeth involved in the fracture lines will survive, be of value for fixation, and cause no trouble. An attempt at early extraction of a firm tooth on a major loose fragment is very traumatic and commonly brings

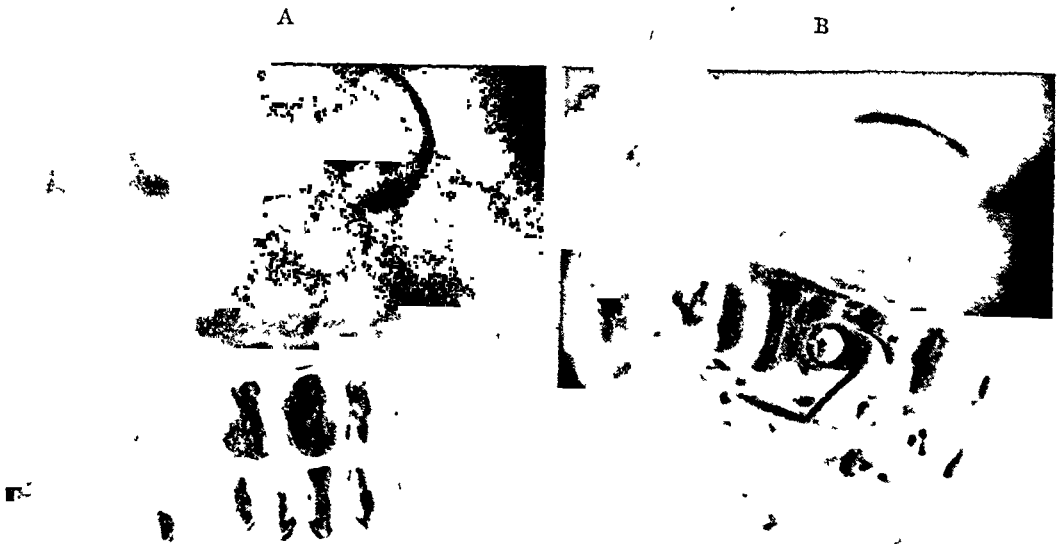


FIG. 5.—Cast metal splint fixation:

Closed cast silver splints cemented on were the standard definitive fixation used by the Unit for missile wounds of the jaws.

A. Shows intermaxillary fixation by wiring the splints together with S.S. wire.

B. Shows intermaxillary fixation and fixation across the fracture site by a locking-bar.

the bone fragment away with the tooth. On the other hand, teeth in the single fracture line of an accidental injury are best removed at primary operation, with the exception of a firmly embedded 8.

8. *Ward Care*.—For battle periods a well-lighted recovery ward, with an experienced staff, is essential.

Feeding in the early stages depends upon a well-organized ward service. The worst wounds depend upon intravenous feeding for the first two or three days. Up to 4 per cent need feeding by an indwelling Ryles tube during the first two weeks. Only four out of 1,000 cases had gastrostomies; in only one was it absolutely necessary.

As early as possible the patient is taught the importance of maintaining a very high standard of oral hygiene by his own efforts with tooth brush, pumice and bicarbonate; special irrigation machines are never used.

IMMEDIATE TREATMENT

This is the treatment of infective complications of bone and teeth, and the provision of definitive fixation.

1. *Definitive Fixation.*—Splints: Sectional cast silver closed-cap splints fitting closely round the gum margin have been the standard splints of this Unit. Open-cap acrylic splints have been used only in a small minority of cases. The fixation of closed cemented silver splints is firmer, particularly for the British soldier whose dentition is often incomplete and irregular. The objection that closed cemented silver splints cause gagging receives no support from our experience of over 800 splints fitted.

Time of application of cast metal splints (C. M. S.): We have seen the results of a large number of cases treated by C. M. S. as a routine primary method of fixation at Forward Hospital or C. C. S. level. The chief disadvantage of Forward splinting is that teeth are often included in the splint, which have to be extracted later—and extraction of a tooth incorporated in a splint may be technically difficult and harmful. Furthermore, the planning and application of a splint is best left until the course of the fracture after the primary surgery is apparent, and the case can be observed and held. There remains the minority of cases that cannot be properly fixed in any other way and in them the inherent disadvantages of Forward splinting must be accepted.

It is important to realize that to immobilize a jaw by wire all that is needed is a yard or so of wire and a pair of Spencer Wells forceps, whereas the use of splints requires a ton of heavy equipment and accommodation for a skilled dental mechanic whose maximum output at pressure is only two sets of splints a day.

2. *Other Methods of Fixation.*—About 90 acrylic, or vulcanite Gunning splints, have been fixed by per alveolar and circumferential wiring in 45 edentulous cases. This probably is a higher proportion of edentulous fractures than would be found in a similar group of U. S. Army personnel. The method gives firm fixation for four to six weeks, which is quite long enough for union in most edentulous fractures. In one case an upper Gunning splint fixed by per alveolar wires was left in and was firm for six months.

Extra-oral Roger Anderson pins have been used by us in only 15 cases, but in these they played a valuable rôle in controlling edentulous posterior fragments involving teeth or compound into the mouth. Sequestration around the pins occurred in one of our own cases, and infection around pins has been seen in seven other cases whose pins were inserted elsewhere. This is the risk of the method. Pins are unsuitable for the early treatment of shell wounds with major bone gaps as they seldom remain firm for more than six to ten weeks, deformity recurs on their removal and nothing has been gained.

Interosseous wiring has been used in 15 cases, and has been uniformly satisfactory in fixing and producing rapid union of edentulous posterior fragments in linear closed fractures.

3. *Sequestrectomy and Drainage.*—The commonest cause of infective episodes, or of a persistent sinus, is sequestration of bone fragments. Jaw wounds which are not healed in two to four weeks should be gently explored by the finger through the wound or a small suitably placed submandibular incision. Sequestra are removed and a drain inserted, and healing is expected in one to two weeks. These operations may yield one to three major sequestra (1 cm. in diameter, or more), or only a number of "seedling" sequestra. Up to the arbitrary time of eight weeks a most conservative policy is followed. Only bone which is certainly dead is removed, and no attempt at full exposure of the fracture site is made.

If the wound is not soft and dry at eight weeks a radical exploration is made through an enlarged or planned incision. All comminuted bone is removed and a drain is left in. At this late operation any bone fragment that is not certainly viable is cleared out, and the bone ends of the major fragments are freshened.

It is axiomatic that healing follows within two weeks or the operation has been inadequate, and must be repeated to avoid the interminable sinuses which occur when the care of these patients is not geared to a time-table.

4. *Soft Tissues.*—There is a useful place at this stage for secondary closure of jaw wounds which were not primarily closed, especially buccal and parotid fistulae. These operations obviate dressings and by stopping drooling from the fistula give the patient great relief.

5. *Secondary Hemorrhage.*—There were 20 cases of secondary hemorrhage. Most of these hemorrhages were minor and readily controlled in bed by simple measures. In six (1 per cent of missile wounds) bleeding occurred from an arterial gusher. These were all controlled by ligation of the external carotid on the same side. None died. The special danger of intrabuccal hemorrhage in cases with I. M. F. is rare, but every M. F. ward should have a wire-cutter and torch easily available.

6. *Teeth.*—Extractions at this stage are indicated when an involved tooth is considered to be the cause of an infective episode or the cause of a persistent sinus internal, or external. This extraction may be difficult or harmful if primary fixation has been by splints rather than by wire. Fifteen per cent of the fractures involving teeth in this series of 1,000 jaw fractures had late extractions.

#### LATE TREATMENT

The scope of late repairs of the M. F. casualties in a Theater of Operations is dictated by military conditions of which the number of hospital ships and number of hospital beds are the chief. In this Theater facial wounds needing tube-pedicle repair have seldom been done, and only a minority of cases with bone gaps (14 out of 52) have been grafted abroad.

Of these 1,000 cases 600 were returned to duty in the Mediterranean. This high proportion has been possible because of the large number of

facial wounds which could be repaired from local tissue, and the small proportion of jaw wounds with bone gaps (15 per cent of missile wounds).

1. *Cancellous Chip Bone Grafts*.—Cancellous chip bone grafts have been used in 14 cases. No graft was inserted earlier than 60 days from date of wounding, and all except three cases were grafted within 100 days from being wounded. In eight cases a graft was inserted one to four weeks after soft-tissue healing. Union times varied from 32 days for 1 cm. gaps to 90 days for gaps of 6-7 cm. There were no complications in this series. All achieved union while under our care, and there has been no trouble of any sort from the iliac donor sites.

TABLE II  
CHIP BONE GRAFTS FOR MANDIBULAR FRACTURES

<i>Total Cases</i> ..... 14	
Gap	Union Time (Days)
1 cm.....	32 (7 cases)
2-4 cm.....	45 (4 cases)
6-7 cm.....	90 (3 cases)

The experience of this Unit with cancellous chip grafts is consistent with that of Plastic Centers in England in showing that this method of grafting is simple, safe and certain. It produces union more rapidly and can be used earlier than can formed cortical bone grafts. This effective method justifies bone grafting of nearly all fractures of bone gaps a month after healing. Its safety is such that we have adopted a policy of bone grafting any case which is not clinically progressing to bony union by 90 days.

2. *Scar Corrections*.—These have been done one to four weeks after final healing. This is much earlier than in civilian practice but we believe it to be the right policy under military conditions. These facial repairs are done by standard methods—by excision, undermining, and a two-layer closure after excision of dogears, or by swinging and rotation flaps or “Z” plastics.

For defects unsuitable for repair by local tissue free grafts have been used; postauricular full-thickness grafts for lower lids and thick dermatome sheets from the abdomen for cheeks and foreheads.

3. *Epithelial Inlay*.—Epithelial inlays are needed at this stage in about 5 per cent of the cases returned to duty within six months of being wounded. The reopened buccal sulcus is a uniformly receptive surface for split-skin born on a detachable G. P. mold fixed to a silver-cap splint. All cases have shown a 90-100 per cent take of the grafts, and dentures have been fitted three to four weeks after operation. Perhaps half the long-term cases need it before their repair is complete and they can wear a denture.

4. *Trismus*.—Trismus is a common sequela of missile wounds involving the muscles attached to the ascending ramus, whether a fracture is present or not. It commonly comes on after the second week.

Prophylaxis consists of chewing gum and the use of a wedge. This is enough for most cases of trismus following I. M. F.

Cases of persistent trismus due to soft-tissue injuries or fractures of the coronoid alone, are forcibly dilated under anesthesia and a prop inserted which is worn continuously for five days and then intermittently for a further ten; this has been uniformly successful and no late recurrences have been seen.

5. *Assessment of Union.*—Union in mandibular fractures is a clinical term judged by the usual clinical standards; namely, that the fracture site is firm to testing, is not tender to direct or indirect pressure, or on chewing. Reliable roentgenographic evidence of bony union is very seldom present before three months, may be much later, and is no help in deciding release of fixation. Union actually occurred somewhat earlier than the times quoted. Testing necessitates release of the fixation, takes time, and so is seldom done oftener than once a fortnight after the expected date of union.

## RESULTS

In this series of complete fractures of the horizontal ramus involving teeth, caused by missiles, 110 cases united while under our care. Most of them were severely comminuted and it is remarkable that severe comminution only delayed union by about a fortnight, even though the comminuted cases often required late sequestrectomies. The analysis also shows that early surgery and fixation of the fracture lead to union one to three weeks sooner and reduce the incidence of late bone infection. The value of early treatment is best seen in comminuted fractures (Table III).

TABLE III

<i>Shell Wounds Causing Complete Fracture of Horizontal Ramus Involving Teeth</i>						<i>Accidental (closed) Injuries Causing Complete Fracture of Horizontal Ramus Involving Teeth</i>			
Total cases treated, 281						Total cases treated, 170			
Total followed through to union, 110						Total followed through to union, 148			
SHOWING RELATION OF UNION TIME TO DEGREE OF COMMINUTION, DAY OF INITIAL FIXATION AND NUMBER OF CASES REQUIRING LATE SEQUESTRECTOMIES									
	Degree of Comminution					Degree of Comminution			
	0	1	2	3	Gap	0	1	2	0
Number of cases.....	6	15	40	40	10	108	30	10	3
<i>Fixed within two days</i>									
Union time (days).....	41	56	58	57	0	46	48	57	0
	(3 cases)	(8 cases)	(21 cases)	(26 cases)		(64 cases)	(21 cases)	(7 cases)	
Cases requiring late sequestrectomies.....	0	0	7	14	8	4	3	2	0
			(8 ops.)	(25 ops.)	(9 ops.)	(6 ops.)	(5 ops.)	(6 ops.)	
<i>Fixed between 2nd and 7th days</i>									
Union time (days).....	51	45	65	76	0	44	51	78	0
	(3 cases)	(7 cases)	(19 cases)	(14 cases)		(44 cases)	(9 cases)	(3 cases)	
Cases requiring late sequestrectomies.....	0	0	9	10	0	4	0	2	0
			(21 ops.)	(16 ops.)		(4 ops.)		(3 ops.)	
Average union times.....	46	51	62	64		45	49	64	

In these tables degrees of comminution are as follows:

0 = single fracture lines.

1 = 1-3 bone fragments between the main fragments.

2 = 1-2 cm. of diffuse fragmentation of the mandible; in missile fractures the comminution is much finer and there is more shattering.

3 = more than 2 cm. of fragmentation, including those of diffuse comminution of the whole of one, or both horizontal rami.

One hundred and forty-eight accidental fractures of the horizontal ramus involving teeth (Table III) were analyzed in the same way for comparison. The classification of degrees of comminution is not strictly the same as missile injuries, are usually much more finely comminuted and the fragments more scattered. In the accidental group as a whole, comminution is less and the wound and associated soft-tissue damage are much less. It is remarkable that the union times of the accidental group are practically the same as the shell group for comparable degrees of comminution; the damage to the soft tissue has apparently no effect on the process of bony union.

The aim of the primary operation is to remove all bone fragments that are infected or nonviable and to preserve all that will survive. If the surgeon is too radical he will create gaps requiring bone grafts unnecessarily. If he is too conservative there will be a high incidence of late sequestrectomies.

A comparative table was prepared to see if there were any grounds for our belief that the early surgery ought to be done by a Forward specialist team. It provided striking evidence. When the early surgery was not done by a specialist team, employing the principles described above, the incidence of bone gaps was exactly the same but late bone infection was nearly three times as common (Table IV).

TABLE IV

SHOWING THE INFLUENCE OF SPECIALISED TREATMENT ON UNION TIME, INCIDENCE OF LATE SEQUESTRECTOMIES AND INCIDENCE OF BONE GAPS IN COMPLETE SHELL FRACTURES OF HORIZONTAL RAMI INVOLVING TEETH

	Cases Treated Throughout*	Cases that Received their Early Treatment Elsewhere†
Total numbers.....	135	146
Average union time (days).....	56 (41 cases)	70 (61 cases)
Bone gaps.....	27	25
Cases that required late sequestrectomies.....	41 (52 ops.)	92 (136 ops.)

\* Cases treated throughout by this Unit; early treatment of bone and soft tissues being as described, in the early paragraphs of this paper.

† Treatment undertaken from the second week.

There were only 22 fractures of the edentulous horizontal ramus in this series; and on this small group one can only say that complications were few and in their absence union took place within three weeks.

One hundred and ninety angle fractures are analyzed separately because of the peculiar problem of controlling the posterior fragment. Unreduced displacement of the posterior fragment considerably delays union and an involved eight is often left, if firm, to control the fragment and avoid displacing it by the trauma of extraction. In missile injuries there is often diffuse shattering of the angle so this policy refers particularly to the accidental group. It does not often lead to suppuration and drainage of the jaw but Table V clearly shows that union takes 10 to 20 days longer when the fracture line involves teeth. All the ten cases that required drainage involved teeth. In four cases primary extraction had been done, and in six the tooth was extracted at the first inflammatory episode. In this group, again, the soft-



tissue injury appeared to have no effect on union time and the accidental and shell fractures with comparable degrees of comminution united at the same rate.

Our standard practice with 128 condylar fractures has been to fix them in proper occlusion for three weeks, and then encourage full function and discharge them a week later. The standard incapacity time is thus a month,

TABLE V

<i>Shell Wounds Causing Complete Fracture of Angle of Mandible</i>					<i>Accidental Complete Fractures of Angle of Mandible</i>				
Total cases treated, 95					Total cases treated, 95				
Total followed through to union, 43					Total followed through to union, 86				
SHOWING RELATIONSHIP OF UNION TIMES TO INVOLVEMENT OF TEETH, TO DEGREE OF COMMUNITION, DAY OF FIXATION AND NUMBER OF CASES REQUIRING SEQUESTRECTOMY					SHOWING THE RELATIONSHIP OF UNION TIME TO DEGREE OF COMMUNITION, DAY OF FIXATION, INVOLVEMENT OF TEETH AND INCIDENCE OF DRAINAGE				
	Degree of Comminution				Gap	Degree of Comminution			
	0	1	2	3		0	1	2	3
Number of cases.....	0	9	18	12	4	65	18	3	0
<i>Fixed within two days</i>									
Union time (days).....	0	48 (6 cases)	47 (8 cases)	55 (4 cases)		39 (33 cases)	50 (5 cases)	70 (1 case) 105 (B.G. 77)	0
Cases requiring sequestrectomy.	0	0	2	2		4 (7 ops.)	1 (2 ops.)	0	0
<i>Fixed between 2nd and 7th day</i>									
Union time (days).....	0	41 (3 cases)	52 (10 cases)	59 (8 cases)		50 (32 cases)	54 (13 cases)	150 (1 case)	0
Cases requiring sequestrectomy.	0	0	4	5 (8 ops.)		3 (6 ops.)	3 (5 ops.)	0	0
Cases involving teeth.....	0	50 (5 cases)	51 (14 cases)	58 (12 cases)		49 (53 cases)	55 (14 cases)	110 (3 cases)	0
Cases not involving teeth.....	0	40 (4 cases)	45 (4 cases)	0		32 (12 cases)	35 (4 cases)	0	0

TABLE VI

<i>Fractures of Condyle of Mandible</i>			<i>Fractures of the Coronoid Process</i>		
	Caused by Shell	Accidental	Caused by Shell	Accidental	
Total number of cases.....	48	80	22	3	
Associated with other fractures of mandible..	20	42	10 (9 A.R.)	2	
Fractures of condyle alone.....	28	38	12	1	
Treatment seen to completion.....	15	36	15	3	
Days under treatment.....	?	Av. 29	Av. 52	Av. 32	
Evacuated (all for other injuries).....	13	2	7	0	
Fixation.....	Av. 28 days (20 cases)	Av. 20 days (25 cases)	10 cases	0	
Major trismus.....	3	0	11	0	
Duration of fixation.....	40, 42, 70 days		0	0	
Condylectomies.....	3	0	2 cases	0	
Sequestrectomies required.....	2 cases (5 ops.)	0	10	0	
Associated lesion of ear, eye, antrum.....	10	0	2	0	
Early major hemorrhage.....	3	0	0	0	
Gagging, requiring molar extraction.....	0	2			

and there were no cases of trismus, and only two that required late molar extraction for gagging (Table VI).

Missile fractures of the condyle are a different class of injury with the risk of damage to the internal maxillary artery where it is relatively inaccessible and of inflammatory complications leading to severe trismus. Hemorrhage is usually controllable by pack and pressure dressing but one case developed a false aneurysm medial to the ascending ramus which healed after external carotid ligation on the same side.

Fractures of the coronoid process (25) were not treated by intermaxillary fixation except when necessary for other associated fractures. They were characterized by a high incidence of trismus and involvement of eye, ear and antrum.

There were 89 incomplete fractures of the mandible involving either the alveolus or lower border. They can usually be treated by complete clearance of bone fragments and closure of the mucosa or skin as the case may be. Dental fixation is not necessary and they are soon fit for duty.

FRACTURES OF THE MAXILLA

Maxillary fractures were present in one-third of the missile wounds in this series (220). They range from the small puncture wound of antrum to hideous disfigurements, with much tissue loss (Table VII).

TABLE VII

Fractures of Maxilla Caused by Shell					Accidental Fractures of Maxilla				
SHOWING TYPE OF FRACTURE					SHOWING TYPE OF FRACTURE				
	Total No. of Cases	State of Maxillary Block				Total No. of Cases	State of Maxillary Block		
		Mobile	Floating	Firm			Mobile	Floating	Firm
No. of cases.....	211	19	19	173		49	8	26	15
With associated fractures of mandible.....	73		24	49		20	3	12	5
Fractures of Maxillary Block seen to union					Accidental Fractures of Maxillary Block seen to union				
Number seen through to union, 18					Number seen through to union, 24				
Table showing influence of day of fixation on union time					Table showing influence of day of fixation on union time				
		Mobile		Floating			Mobile		Floating
Number of cases.....		7		11		6			18
Union Time (days after injury)									
Fixed within 14 days.....	27 (3 cases)			36 (8 cases)		31 (5 cases)			28 (2 cases)
Fixed after 14 days.....	59 (4 cases)			53 (3 cases)		21 (1 case)			46 (16 cases)
Complications:					Complications <sup>9</sup>				
Antral infection.....			15%		Antral infection.....			8%	
Cases needing Caldwell-Luc.....			2%		Cases needing Caldwell-Luc.....			4%	
Major hemorrhage (early and late).....			10%		Tracheotomies.....			1 case	
Tracheotomies.....			5%		Death.....			2 cases	
Death.....		5-10%		2-3 due to associated cranial damage				(avoidable)	
Associated injury of:					Associated injuries:				
Eye.....			25%		Skull.....			20%	
Ear.....			5%		Eye.....			40%	
Brain.....			5%		Major limb fr.....			16%	

In 20 per cent the tooth-bearing segments are displaced and either "mobile" requiring a period of dental fixation in occlusion, or "floating" implying a maxillary block which is so loose that interdental fixation is not enough to control it; the maxilla must, in addition, be supported by fixation to the skull.

Apart from this, maxillary wounds are chiefly important because of complicating injuries. The most common of these is a fracture of the mandible which was present in 40 per cent of all cases. Eye damage—commotion, detached retina or direct injury—was present in 25 per cent of fractures of the maxillary block; 10 per cent had major hemorrhages; and fracture of the anterior cranial fossa with associated brain damage was a critical factor in nearly all the most serious cases and caused two-thirds of the deaths (5 or 10 per cent of all maxillary fractures).

The treatment of the antral wound has been described—wound excision, bone clearance, nasal antrostomy and closure whenever possible.

The treatment of cases with gross damage is to accelerate healing with the least possible deformity and without prejudicing later reconstructions. It is often possible to assist healing by carefully suturing the skin tags of a disruptive wound, and in some cases by mucocutaneous suture.

The displaced upper jaw presents many special problems. Even the most freely mobile are almost always firm to testing after 30 days fixation, but this is misleading; a mandible that is clinically firm soon goes on to bony union, but the maxilla may long remain in a condition of tough fibrous union which yields over a period of weeks if fixation is released and may redisplace or become mobile again.

It is, therefore, always necessary to reduce the maxilla into proper occlusion on the mandible at the earliest opportunity and keep it in position by I. M. F. until it is united. Even so, malocclusion recurs later in a proportion of cases but can then usually be successfully reduced by C. M. S. and powerful elastic traction or continuous traction in bed by weight and pulley.

In a floating maxilla the nasal air-way is often blocked and if early I. M. F. were done under military conditions a high proportion would require tracheotomy or they would die of suffocation. Table VII, and our experience, show that there is little disadvantage in maxillary fractures in delaying I. M. F. until the nose unblocks in five to ten days, so it has been our practice to do so, rather than do a prophylactic tracheotomy in most of the cases.

The standard method of fixation for the floating maxillary block is to apply a C. M. S. with one to three rods projecting from it through the mouth and join these to a well-fitting P. O. P. headband incorporating a metal bracket, by universal joints and one to three stout vertical connecting rods. The whole system must be sturdy and rigid.

When the upper jaw is edentulous or fractured in several places, and when there is an associated fracture of the lower jaw, the method must be modified accordingly.

Slight antral infection occurred in 15 per cent of the missile injuries but settled within six weeks on simple local treatment. Only 2 per cent of 220 wounds needed a Caldwell-Luc operation, and this was not done before the sixth week.

#### DEATHS

The experience of World War I was that the chief causes of death in M. F. casualties were hemorrhage and suffocation in the early stages, and chest complication and secondary hemorrhage later. These are the causes of death in this series, too, but we believe that there are fewer deaths and that secondary hemorrhage is rare and seldom fatal. In the M. F. casualty the risks of treatment can, in inexperienced hands, be much greater than the risks of the injury. This holds especially for the anesthetic risks. A major factor in the reduced mortality has been the provision of an M. F. anesthetist experienced in the intubation difficulties and the postanesthetic care of the primary operation upon these cases. The decrease in secondary arterial hemorrhages to 1 per cent is attributed to thorough early surgery of bone fragments and soft tissues and to a well-organized ward care for these jaw casualties.

The uncomplicated M. F. casualty is not often in urgent need of plasma or blood. In the Cassino battle, in which 220 M. F. casualties were treated in 12 days, only 10 per cent were given early blood or plasma, and in only about 1 per cent of these cases was transfusion life-saving. These measures have played a small part in reducing the mortality.

The majority of the deaths from infective causes—secondary hemorrhage and pulmonary infection—had had full parenteral penicillin. We have little evidence that penicillin can further reduce the mortality in M. F. casualties which have had thorough surgery.

Of this series of 1,000 jaw fractures 33 died. In 14, death was due to an associated grave injury of brain or spinal cord; and in four others (blast abdomen, infected hemothorax, sucking wound of chest, gas gangrene of thigh), the M. F. lesion was not a major factor in the death.

There remain 15 cases in which the M. F. injury was the cause of death. This gives a gross mortality of 1–2 per cent for M. F. casualties with bone damage.\* The pure mandibular open wound has a mortality of .5 per cent; the closed mandibular fracture caused no death in this series. The gross maxillary mortality was 9 per cent, due to the high incidence of associated fatal brain wounds. The mortality of combined wounds of the pharynx and jaws was 6 per cent; these were all injuries of the laryngopharynx; none of the oro- or nasopharyngeal wounds died or developed deep neck or mediastinal infection.

Half the total deaths occurred within the first week. The causes of early deaths were:

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\* Mortality is less than .5 per cent if all wounds involving facial soft tissues and nose are included.

3 cases of hemorrhage:

Vertebral artery.

Innominate artery.

Internal maxillary artery.

1 case of suffocation.

1 case of gas gangrene of muscles of mastication (also of brain).\*

1 case of carotid thrombosis and hemiplegia.

1 case of toxemia—a massive jaw wound, who also had a subdural hematoma.†

Of the seven deaths occurring after the first week, five were due to pulmonary complications. One was a ruptured false aneurysm of the internal maxillary artery (who also had an empyema and a fractured femur), and one a case of suffocation.

Three of the pure M. F. deaths were due to avoidable accidents and occurred in dark wards or tents full of fresh battle casualties. They serve to emphasize the need for a well-lighted recovery ward for M. F. cases.

This experience indicates that in M. F. casualties, which reach C. C. S. level, the chief causes of early death remain in this war as in the last—hemorrhage and suffocation; late death is, again, most commonly caused by pulmonary complications.

#### SUMMARY

The treatment of maxillofacial casualties in North Africa and Italy is described, with a note on the British Army arrangements for their care.

One thousand jaw fractures are analyzed. Results and different methods of treatment are discussed.

The rôle and importance of primary soft-tissue repair are stressed.

The value of cancellous chip bone grafts in the surgery of the mandible is shown.

The mortality, early and late (gross 1–2 per cent), and the incidence of arterial secondary hemorrhage (1 per cent) in jaw wounds are given and analyzed.

Our thanks are due to the Consulting Surgeons Brigadiers Weddell, Stammers, and Edwards, A.M.S., under whose direction and by whose help this work was done.

The great majority of the anesthetics for these cases were given by Major G. K. T. Roche, R.A.M.C., to whose expert anesthesia the Unit has owed its low incidence of anesthetic complications.

The treatment of the African and Italian casualties was made possible by the work of the Theater Staff—Sister P. Clutton Qaimns (R.), Cpls. Cordery and Parker, Pvts. Farwell and Waller, R.A.M.C., who made the complete arrangement for 100 to 500 operations a month for 2.5 years.

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\* Confirmed by autopsy section and culture.

† Died six hours after admission, 24 hours after being wounded. Autopsy showed a purulent pericarditis and a soft enlarged spleen.

Major A. Green, A.D., Corps., and Capt. W. Grossman shared in the care of the African and Italian casualties.

# REPAIR OF SOFT-TISSUE WAR WOUNDS

LT. COL. BENJAMIN W. RAWLES, JR., M.C., A.U.S.\*

APPROXIMATELY 85 to 90 per cent of uncomplicated soft-tissue war wounds can be closed successfully four to ten days after adequate débridement.<sup>1, 2, 3</sup> This policy of early closure was generally adopted in the Mediterranean Theater of Operations in the winter of 1943-44. At first only the uncomplicated wounds were so closed, but with the aid of penicillin to control infection and a blood replacement program to correct anemia, early reparative surgery of extensive and even complicated wounds also was undertaken. The general principles underlying this program have been reported by Churchill.<sup>4</sup> This paper reports the experiences in a General Hospital in the Mediterranean Theater of Operations with the reparative phase of the management of soft-tissue wounds.

The goal of reparative surgery in an Overseas Theater is to obtain a closed wound: First, so that as many men as possible may be salvaged for further duty in the Theater; and, second, so that the reconstructive phase of wound surgery done in the Zone of Interior may be undertaken at the earliest possible time. Repair of soft-tissue wounds may be undertaken (a) early (between the fourth and tenth days); (b) late (after ten days); or (c) by a planned stage method which will be described. In any case, the actual repair is accomplished by either (1) approximation of skin edges; (2) skin grafting; (3) simple plastic procedures, such as advancement of flaps; or (4) a combination of the three methods.

## COMPARISON OF METHODS

Early repair is more successful than late repair because of a low incidence of infection. Technically, it is also more easily accomplished and results in better function of the injured part because of minimal scar tissue formation. The contraindications to early repair are (1) frank purulent discharge from the wound; (2) presence of devitalized tissue in the wound; (3) redness, tenderness and induration about the wound edges; or (4) abnormal elevation of temperature. Experience during the Italian Campaign has shown that these contraindications are rarely encountered if débridement has been adequate, so that repair can be undertaken without delay. If there is only minimal infection present, the wound is allowed to "clean-up" with the aid of moist and resilient pressure dressing. This may delay repair beyond the ideal four- to ten-day period. In other cases the planned stage method of repair is carried out. The first stage consists of the removal of devitalized tissue and the drainage of pus pockets. Four to six days later the second stage (repair) is carried out, the viable tissues having been protected in the intervening period by the administration of intramuscular penicillin. The correc-

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tion of anemia with transfusion of whole blood plays an important part in the success of this method.

Early repair is seldom complicated by serious infection for several possible reasons: First, the wound by the end of the fourth day has developed a strong resistance to infection; second, there is little chance for further wound contamination since the dressing applied after initial surgery is usually not changed until the time of reparative surgery; and, third, it is usually accomplished with a minimum of manipulation or trauma. Partial or total failure results, on the other hand, in a greater percentage of late repairs because of infection. There are several reasons for this. The longer a wound is open, the greater chance there is for it to become contaminated and, therefore, for it to serve as a source of infection. In late repairs dissection is necessary into fresh tissues which have not developed resistance, since the wounds have to be excised in whole or in part and the edges undercut. The difficulty of hemostasis and the unintentional closure of some of these wounds under tension are additional factors that increase the incidence of infection.

Repair between the fourth and tenth days is technically more easily accomplished than late repair because of the pliability of tissues due to the absence of excessive scar tissue at this time. This is very important in extensive wounds when, even with minimal skin loss, there is wide separation of skin edges. These can usually be approximated early by simple suture, while if repair is delayed, the tissues become so contracted and fixed by scar tissue that skin grafting or other plastic procedures have to supplement wide undercutting of the wound edges before a closed wound can be obtained.

*Analysis of Cases.*—During the first three months of 1944 a careful check of early and late closure was kept on 691 wounds in 422 battle casualties. Results were classified as "A" when healing to all intents and purposes was *per primam*; "B" when healing was with minimal reaction, such as serum and stitch infections, but without loss of skin approximation; or "C" when there was gross infection with partial or total separation of skin edges.

In 391 of the wounds, closure was by simple approximation less than 12 days after débridement. Healing was classed as "A" in 370, or 94.6 per cent; as "B" in 15, or 3.8 per cent; and as "C" in 6, or 1.5 per cent.

Closure was done late in 300 wounds. Sixty of them were closed by simple approximation but all were done 12 days or more after débridement. In this group healing was "A" in 37, or 61.7 per cent; "B" in eight, or 13.3 per cent; and "C" in 15, or 25 per cent. Partial or total excision before closure was done in the remaining 240. Healing was classed as "A" in 180, or 75 per cent; as "B" in 31, or 12.9 per cent; and as "C" in 29, or 12.1 per cent. The figures for the combined late group were "A" 72.3 per cent; "B" 13 per cent; and "C" 14.7 per cent.

#### EARLY REPARATIVE SURGERY

*Preparation.*—Patients with soft-tissue wounds usually reach the General Hospital in the Base by the third, fourth or fifth day after injury. Because

there are so many advantages of early repair, it has been described by Rogers<sup>5</sup> as a "surgery of necessity." Operation is delayed long enough, however, for the patient's condition to be checked and to allow him to recover from the fatigue resulting from his transportation. Blood values are determined when indicated and anemia, if found, is corrected by transfusions of blood. Additional roentgenologic examinations were also made, if necessary, to determine the presence or location of metallic foreign bodies. If temperature is not abnormally elevated, the patients are taken to the operating room, preferably on the fourth or fifth day, and the wound exposed for the first time since initial surgery under aseptic conditions. Clinical judgment rather than bacteriologic studies determines whether or not the wound should be closed at this time. Experience with the management of over 3,000 casualties with soft-tissue injuries has shown that this can be done successfully even when the wound surface appears "mucky." We know that the surfaces of many of the wounds are contaminated and a bacteriologic report would only confuse the issue and unnecessarily delay repair. A majority of wounds are closed under intravenous sodium pentothal but if the operation is likely to extend much beyond 30 minutes, nitrous oxide-ether inhalation anesthesia is preferred. The skin about the wound is cleansed with ether and then painted with one of the accepted antiseptics. The usual wound in the early period has a freshly-cut appearance which "invites" repair. If blood clots are present, they are carefully removed. Small metallic foreign bodies not found at initial surgery are not searched for, unless it is felt that they can be readily located without too much disturbance of the wound or if their location near vital structures or joints may cause future trouble. They are rarely responsible for the failure of wound healing.

*Repair by Approximation of Skin Edges.*—In the majority of soft-tissue wounds, closure is by the simple approximation of wound edges provided there has not been excessive loss of skin. Towards the end of the period in which early closure is possible the wound edges begin to roll in. If this is the case, they are gently freed up with a blunt instrument. Approximation is by simple or vertical mattress sutures of silk or silkworm gut on large skin needles. Wound edges are sometimes so widely separated because of edema that they cannot be reapproximated with these types of sutures. A far-near-near-far type of tension suture, such as is commonly used to close the skin of the chest wall after radical mastectomy, is of value under these circumstances. Approximation is made under moderate tension in violation of this principle of surgery because as soon as the wound is closed edema subsides and the tension is lessened before strangulation of the incorporated tissues takes place. An attempt is made to encompass the wound, or at least the open portion of it, with the sutures in order to obliterate dead space. The fascia is included in the sutures but no attempt is made to do a separate layer suture. Only occasionally is a symptomatic muscle hernia seen because of failure to suture separately the fascia and these are usually small defects which are easily corrected if necessary. On the other hand, we feel that



routine layer closure would result in a higher incidence of infection because of the additional tissue dissection required and because of the presence of buried suture material. Obliteration of dead space is not difficult in the majority of wounds because of their anatomic location on the extremities. They are usually located in the long axis of the limb and the closure of the wound snugs the skin around the part and aids in obliteration. A resilient pressure dressing is of further aid. Wound drainage is only employed when

A

B



FIG. 1.—Case 1: Repair of wound by simple approximation five days after débridement of perforating wound. (A) At time of closure. (B) After removal of sutures 14 days after closure.

deep pockets cannot be obliterated; when there is profuse drainage from a long perforating wound; or when there is surface infection, as is described in Case 3. Rubber tissue is the material of choice for drainage.

The following case illustrates repair by reapproximation:

**Case 1.**—(Fig. 1): An American soldier, age 19, was wounded in action in the right buttock by a high explosive shell fragment, February 29, 1944, on the beach-head at Anzio, Italy. The wound was perforating, with the wound of entrance on the lateral aspect of the buttock and the wound of exit on the mesial aspect of the upper thigh. Débridement was done at an Evacuation Hospital 16 hours after injury. A diagnosis of anaerobic cellulitis was made at this time. The tract was opened widely throughout its entire length, which necessitated almost complete division of the gluteus maximus muscle. He was evacuated by boat to a General Hospital, in Naples, where he was received March 3. He was found to be in good condition and delayed primary suture of the incised wound, which measured 33 x 7 cm., was done March 5 (five days after injury), under sodium pentothal intravenous anesthesia. The wound was clean and healthy in appearance. The wound surface was dusted with sulfanilamide powder and closed with silkworm gut sutures. It healed uneventfully except for minimal drainage

## SOFT-TISSUE WAR WOUNDS

at the mesial angle. Sutures were removed on the 10th postoperative day. The only chemotherapy was sulfadiazine by mouth for seven days after wounding. He was discharged to duty after reconditioning on May 11, 72 days after injury.

A



B

FIG. 2.—Case 2: Repair of wound with extensive skin loss by partial approximation of skin edges and skin grafting eight days after débridement. (A) At time of repair. (B) At time of first dressing 12 days after repair.

*Repair by Skin Grafting.*—When skin loss or edema does not permit approximation of skin edges or only allows partial approximation, the wound is covered with a split-skin graft in preference to rotation or advancement of skin flaps. We have rarely employed the latter method, but occasionally it

may be useful. Complicated plastic procedures are better undertaken after the wound has healed, edema has subsided, and the danger of lighting-up infection has passed. Skin grafting is nearly always successful on a fresh wound. The grafts are fitted to the outline of muscle groups and into pockets and crevices when necessary. A resilient pressure dressing is employed.

**Case 2.**—(Fig. 2): An American soldier, age 29, was wounded in action by a rifle grenade on March 18, 1944, at 2300 hours, on the beachhead at Anzio, Italy. He received multiple wounds but the most serious was an extensive avulsed type of wound of the right arm with severe compound, comminuted, fracture of the humerus. Débridement was done at an Evacuation Hospital shortly after injury. He was evacuated on March 23 to a General Hospital, in Naples, where he was found to have an extensive soft-tissue defect on the right upper arm, measuring 30 x 22 cm., with numerous exposed fragments of bone in the wound and with copious drainage of serum. Intramuscular penicillin therapy in doses of 25,000 units every three hours was started, and the anemia was corrected with transfusion of blood in preparation for reparative surgery. On March 27 (eight days after injury) under nitrous oxide-ether anesthesia, with the aid of Major R. D. Butterworth in the management of the fracture, all loose bone fragments were removed, the main fragments interlocked, and exposed bone covered with muscle. The upper and lower ends of the wound were closed with silkworm gut, but a defect 28 x 20 cm. remained. This was covered with small split-skin grafts which were fitted to individual muscles and into crevices. They were not sutured in place. A resilient pressure dressing and a plaster shoulder spica, with the arm at 80° abduction, was then applied. The wound was exposed through a window in the encasement 12 days later and found to be healing satisfactorily, with practically a 100 per cent take of the grafts. Unfortunately, the fracture of the humerus angulated slightly and a spike of bone had protruded in the center of the wound. The soldier was evacuated to the Zone of Interior on April 28 (41 days after injury) with a closed wound.

**COMMENT:** This wound was complicated by a compound fracture but it illustrates the repair of a wound with extensive loss of skin. Internal fixation of the fracture probably would have prevented the protrusion of the bone through the wound, but this program had not been undertaken at the time. This patient later required bone and soft-part reconstructive surgery, but it was undertaken at a much earlier date. Also, as a result of the early reparative surgery, chronic infection and debilitation from the loss of serum from a large open wound was prevented.

#### LATE REPARATIVE SURGERY

Closure after the tenth day is not by choice, but either because of the contraindications previously described or because evacuation to the Base is delayed by chest, abdominal or other serious wounds beyond the period in which early closure can be done. The granulating wound often becomes infected as a result of repeated contamination at the time of change of dressings and is a frequent cause of failure of wound healing. Careful preoperative preparation is, therefore, necessary. Moist saline dressings or pressure to "dry out" the granulations are sometimes necessary to prepare these wounds for surgery. In the case of large or deep wounds the skin edges only are excised and undercut and approximation made over the granulating bed. This

eliminates much bleeding and reduces the extent of tissue spaces that are opened by dissection. In small wounds it is usually more satisfactory to excise the wounds *en bloc*. Because of fixation and scar tissue or because of loss of skin, wound repair often must be accomplished by skin grafting or other plastic procedures instead of by simple suture. As has been pointed out previously these procedures are more difficult and not as successful as when done early.



FIG. 3.—Case 3: Repair by stage method. Gastrocnemius and soleus muscles removed six days after initial debridement and repair done five days later. (A) and (B) Shows appearance and function of leg 40 days after injury.

#### STAGE REPARATIVE SURGERY

Some wounds when seen in the General Hospital after initial surgery are found to be infected usually because of devitalized tissue that was not recognized at the time of débridement or because of retained foreign material, usually nonmetallic. Many of these cases are handled by a planned two-stage procedure. Secondary débridement and the establishment of adequate drainage is first done, and five days later the wound closed in the same manner as described for early repair. The viable tissues in the intervening time are protected against infection by systemic penicillin and anemia is corrected with transfusions of whole blood. Two case reports will best illustrate the details of this method:

Case 3.—(Fig. 3): An American soldier, age 24, was wounded in action in the posterior aspect of the upper third of the right lower leg by a high explosive shell frag-

ment, September 29, 1944, in Southern France. The wound was lacerating in type and divided the gastrocnemius and soleus muscles near their origins. Débridement was done at an Evacuation Hospital several hours later and a circular encasement applied. He was evacuated by air, September 30, to a General Hospital, in Naples. He was comfortable and in good general condition on admission. He was, therefore, scheduled for inspection of the wound and reparative surgery, if indicated, on October 3 (six days after injury). During the intervening period the temperature had been elevated between 99° and 99.6° F., but because of the description of an extensive wound, this was not thought to be abnormal. When inspected in the operating room, the distal ends of the gastrocnemius and soleus, however, were found to be gangrenous due to ischemia. Both muscles with the tendo achillis were removed under intravenous sodium pentothal supplemented by nitrous oxide-ether inhalation anesthesia. The wound was dusted with sulfanilamide powder and a resilient pressure dressing with dry, fine-mesh gauze applied next to the wound. A posterior plaster splint completed the dressing. The patient had received penicillin intramuscularly in doses of 25,000 units every three hours since wounding, and this was continued. He was given 500 cc. transfusions of whole blood on October 3, 4 and 6, to correct anemia, and on October 8 (five days after the first stage), under intravenous sodium pentothal anesthesia the 40-cm. longitudinal wound, made for removal of the gastrocnemius and soleus muscles, was closed with silkworm sutures. The irregular defect over the original wound, which measured 15 cm. in diameter and which could not be closed, was covered with split-skin grafts. A resilient pressure dressing with a circular plaster encasement was applied. Penicillin therapy was continued for seven days. Healing took place with minimal reaction and the skin grafting was 100 per cent successful. Sutures were removed on the 12th postoperative day. Physiotherapy was started on November 7, and when evacuated to the Zone of Interior, December 23 (87 days after injury), he was walking without aid and with only a slight limp. A letter received from the soldier, dated February 21, 1945, stated that he was getting along fine.

COMMENT: Because of the gangrene of the soleus and gastrocnemius muscles, serious consideration was given to amputation of the leg. This soldier now has a useful leg, with surprising ability and power of plantar flexion.

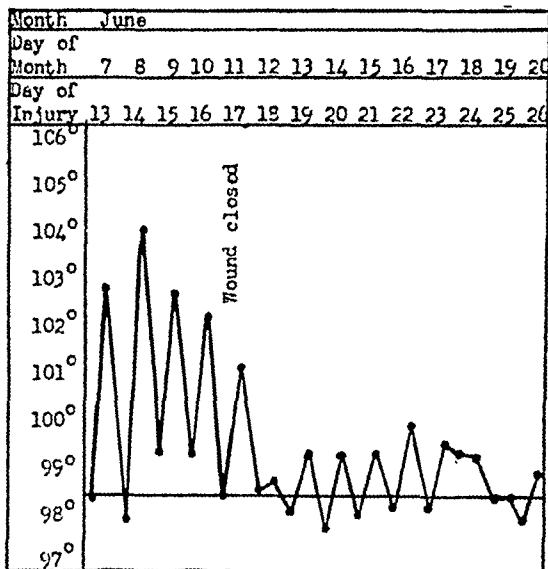
Case 4.—(Fig. 4): An American soldier, age 28, was wounded in action in the anterior lateral aspect of the upper third of the right thigh by a high explosive shell fragment, May 25, 1944, near Cisterna, Italy. The wound was penetrating in type. Débridement of the wound and removal of the shell fragments was done shortly afterwards at an Evacuation Hospital, and the patient evacuated, on May 28, to a General Hospital, in Naples. Examination on admission revealed an acutely ill soldier with a temperature of 104° F., and a pulse of 112. Inspection of the wound, which measured 8 x 3 cm., revealed old blood mixed with gas bubbles exuding from it. The area about the wound was acutely tender and swollen. A tentative diagnosis of anaerobic cellulitis rather than *Clostridial* myositis was made.

Under ether inhalation anesthesia, the thigh was opened widely by an incision that extended from the suprapatellar region up the anterior lateral thigh to a point just below the anterior superior iliac spine, and then extending laterally and upwards for an additional ten centimeters. An incision was made in the lateral aspect of the wound edge to afford adequate exposure. Hemorrhage had dissected between the tissue planes of the muscles of the anterior and lateral thigh, and the vastus lateralis and the muscular portion of the tensor fascia lata were gangrenous. These were excised, muscle planes opened widely, and all clotted blood carefully cleaned out. The wound was filled with activated zinc peroxide paste, and a dry, fine-mesh gauze dressing applied. *B. subtilis*,

A



B



C

D

FIG. 4.—Case 4: Repair by stage method. Secondary débridement done three days after initial débridement, and repair completed 14 days later. (A) At time of repair. (B) Temperature curve immediately before and after closure of wound. (C) Appearance of wound 14 days after closure. (D) Soldier in January, 1945.

*Streptococcus viridans* and micrococci were cultured from the wound. Penicillin, which he had received intramuscularly in doses of 25,000 units every three hours since initial surgery, was continued. A transfusion of 500 cc. of whole blood was given in the operating room and a second on the return of the patient to the ward. There was such a profuse seropurulent discharge from the wound that the dressings had to be changed at the end of three days and thereafter at similar intervals. There was a momentary drop in temperature after surgery but later it ranged between 100° and 103° F. The second stage (repair) was, therefore, delayed. On June 8, the dressing was found soaked in blood. The source was not found since all bleeding had ceased when the wound was

examined. In view of the hemorrhage it was decided that it would be wise to go ahead with wound closure in spite of the gross contamination of the wound surface and the elevated temperature. The blood values at this time were: red blood count 2,190,000, hemoglobin 7.5 grams per cent, hematocrit 22 per cent and serum protein 5.15 mg. per cent. He was given 2,000 cc. of blood in the next three days to correct the anemia. Re-approximation was done on June 11 (14 days after secondary débridement), under nitrous oxide-ether inhalation anesthesia.

When old clotted blood was cleaned out from beneath the upper portion of the sartorius muscle preparatory to closure, there was a gush of arterial blood that carried a distance of 15 feet. This was found to be coming from a hole in the superficial femoral artery. The hole was obstructed with the nose of a Kelly clamp to control bleeding while suture ligatures of plain No. 1 catgut were placed. When tied, these satisfactorily closed the defect. The skin edges were then approximated under considerable tension with silkworm gut sutures. Small rubber tissue drains were inserted at several points. Following closure the temperature dropped to normal where it remained except for minor elevation up to 99° F. Penicillin was continued for seven days after closure. Healing took place with a minimum of reaction and sutures were removed on the 12th postoperative day. The patient was given a total of 5,000 cc. of blood. Physiotherapy was begun on July 2, and when he was evacuated to the Zone of Interior, August 21, his wounds were firmly healed but there was restriction of knee flexion to 90°. A letter received, dated January 10, 1945, states that he has excellent function of the leg.

COMMENT: Surface infection in extensive wounds may cause a marked febrile reaction but, if gross devitalized tissue has been removed, repair can be successfully undertaken with the aid of penicillin and blood replacement therapy. We have had similar experiences in several other cases. Delay in closure in this case might have resulted in fatal hemorrhage from erosion of the femoral artery. Repair at a later date, also, would have been difficult and probably would have required skin grafting or other plastic procedures.

#### AFTER CARE OF WOUNDS

There are a number of things in the after care of repaired wounds which deserve to be stressed. The adjacent joints are splinted to insure rest of the part and a resilient pressure dressing is applied to aid healing by preventing the stasis of fluids in tissue spaces. Sutures are left in place from 10 to 12 days, since healing is probably slower after either early or late delayed closure than after a primary closure. If the patient does not have an abnormal rise in temperature or discomfort in the wound area, the original dressing is not disturbed except for the removal of sutures, unless drains have been inserted. These are removed usually on the fourth postoperative day. When infection develops in a wound, conservatism is practiced. By the judicious removal of an occasional suture and the application of moist dressings of magnesium sulphate or boric acid solution, approximation may be maintained at least in part. Physiotherapy in the form of whirlpool baths, active and passive exercises, and heat is begun as soon as the wound is firmly healed.

#### VALUE OF CHEMOTHERAPEUTIC AGENTS

Penicillin is a valuable adjunct to successful reparative surgery. It is given intramuscularly in dosages of 25,000 units every three hours to nearly

all battle casualties from the time of their initial surgery until the condition of their wounds can be evaluated in the Base. Many of the less severe soft-tissue wounds are repaired without further penicillin or sulfanamide therapy. The program of early soft-tissue repair was successfully underway before penicillin became generally available. Before then sulfadiazine was given orally to all battle casualties for seven days after injury. Penicillin is continued for several days after the repair of wounds in which there has been extensive muscle damage, particularly as a safeguard against the development of *Clostridial* myositis. It is given in all cases treated by the stage method. Some wounds have been dusted with sulfanilamide powder when there was some question as to surface contamination but as more experience has been gained its use has been almost entirely discontinued.

#### REHABILITATION OF THE LIGHTLY WOUNDED

The lightly wounded form a valuable potential reserve for the Army, and if the greatest possible number are to be salvaged for further duty in the Theater, rehabilitation requires careful attention. The further a soldier is evacuated from the front and the longer he is away, the more difficult it is to return him to duty. Lightly wounded casualties are not evacuated any further to the rear than is compatible with adequate treatment and the tactical situation. In the General Hospital in the Base, efforts are directed towards weaning the patient from crutches and cane and from an inside hospital bed as rapidly as his condition will warrant. He is required to wear his combat shoes instead of slippers as soon as possible, as they apparently greatly aid in his rehabilitation by giving his feet proper support. Special attention is paid to the conditioning of quadriceps muscles because of the disability that results from disuse atrophy. This is particularly a problem when the wounds involve only one extremity. Natural favoring of the part causes the patient to limp, which increases the atrophy of the muscle. The atrophy further exaggerates the limp and the more he limps the greater the atrophy becomes. This vicious circle is sometimes difficult to break. He is moved to a ward tent where he sleeps on a cot as soon as his wounds do not demand active attention. This is usually between two or three weeks after injury in the more lightly wounded. This move is deliberately made as a part of mental reconditioning that is often necessary for return to duty even though sufficient inside beds may be available. If a patient spends his entire period of convalescence in one place, he is apt not to be keenly conscious of the improvement he has made. This procedure also allows the more recently injured casualties who require active therapy to be concentrated in one place. When he is a little stronger, he is evacuated to the convalescent section of the hospital, where he hikes, drills, takes calisthenics, participates in athletic contests and performs other duties about the hospital on a graded basis depending on his physical condition. Lectures are given by convalescent officers on the present tactical situation and on subjects of military science. The patient is usually held in this section for two weeks. He is checked at least



twice a week by his original ward surgeon to determine progress and to determine when he is ready to return to duty. Every effort is made to build up a man's unit pride by asking him questions about it or by commenting on its good record. Many men can be returned straight to duty from this section but others require additional reconditioning, and are sent to a reconditioning company for a period of three weeks. They are checked by a medical officer at the end of this time and, if not ready for discharge, are either held for an additional period or are returned to the hospital for further study and disposition by his original surgeon.

#### SUMMARY AND CONCLUSIONS

1. The goal of reparative surgery of soft-tissue war wounds in an Overseas Theater of Operations is to obtain a closed wound: First; so that as many men as possible may be salvaged for further duty; and, second, so that the reconstructive phase of wound surgery done in the Zone of Interior may be undertaken at the earliest possible time.

2. Early repair is more successful than late repair because of a lower incidence of infection and, also, is more easily done because of the greater pliability of the tissues at the time.

3. A two-stage plan of management is often employed in some wounds that are still infected or still contain devitalized tissue. The wound is cleaned up at the first stage and, five days later, it is repaired, infection having been controlled by intramuscular penicillin in the meantime.

4. Repair in any case is accomplished by either (1) approximation of skin edges; (2) skin grafting; (3) simple plastic procedures, such as advancement of flaps; or (4) a combination of the three methods.

5. Penicillin therapy and the correction of anemia with transfusions of blood are of great value as adjuvants to the repair of extensive or complicated wounds.

6. Rehabilitation is stressed in order to salvage the largest possible number of the more lightly wounded for further duty in the Theater of Operations.

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## PULMONARY EMBOLISM

A STATISTICAL STUDY: WITH PARTICULAR REFERENCE TO THE VALUE OF CERTAIN PREVENTIVE MEASURES

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IT IS UNNECESSARY to point to the importance of the subject of pulmonary embolism to justify this study and report. Although several preventive measures have become available during the past few years, the number of surgical patients who die from this cause is still too large. This review of the Henry Ford Hospital material was undertaken at the suggestion of Dr. Roy D. McClure. It is concerned with 118,611 operations performed in a 21-year period, from 1924 through 1944. Two hundred and eighty patients had pulmonary emboli, of which 78 were fatal. The complication was responsible for the death of one patient in each 1,500 operated upon for all reasons. The diagnosis was established by autopsy in 70 per cent of the fatal cases.

The yearly incidence of embolic episodes is shown in Table I. The first two-thirds of this table is inserted more to show the source of the 280 cases analyzed than to give an absolutely accurate picture of the incidence of the complications over the entire period. It is well known that a wave of interest in a subject produces an increase in the number of diagnoses. For example, the table indicates that in 1937 there were only six nonfatal infarcts, while in 1941, with no increase in the number of operations, there were 30. For locating cases previous to 1938, we were dependent on the regular hospital indexing system. Since that time, the case numbers have been obtained from the minutes of the monthly surgical staff meetings which are attended by operating surgeons, residents, interns and anesthetists. In these meetings there has been a reasonably thorough reporting and appraisal of all embolic complications. Attention is called to the fact that in the year 1930, before the days of heparin for clinical use, dicumarol, femoral vein ligation and early ambulation, there was not a single fatal pulmonary embolus, while in 1943, when all of these preventive measures were available, there were eight! However, it can be stated that none of these eight cases was given specific prophylactic treatment. The fatal episode was without warning in seven cases; in the remaining case, death occurred before the recommended vein ligation was carried out.

All cases, both fatal and nonfatal, have been tabulated with regard to sex, age, type of operation and the postoperative day of the attack. An analysis has been made of the chief symptoms of the cases who survived and two tables relating to fatal episodes are given.

*Sex.*—In Table II, it will be noted that both fatal and nonfatal embolism

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occurred more frequently in men than in women, the ratio being approximately 3:2. This is in agreement with the Mayo Clinic study<sup>1</sup> of 172,888 operations, which showed an incidence of 0.605 per cent of total embolism for men and 0.442 per cent for women.

*Age.*—It is well known that the complication of pulmonary embolism affects the older age-groups most often (Table III). In this series, pulmonary infarct occurred only once in persons under 20 years of age. All embolic

TABLE I  
YEARLY INCIDENCE OF EMBOLISM AND INFARCTION

Year	Operations	All Embolic Episodes	Fatal Embolisms
1924.....	5608	6	3
1925.....	5479	9	4
1926.....	5674	7	3
1927.....	4926	10	4
1928.....	5300	13	6
1929.....	5845	12	5
1930.....	5147	4	0
1931.....	4917	14	6
1932.....	4748	5	1
1933.....	3755	4	0
1934.....	5425	12	1
1935.....	6066	14	4
1936.....	6056	13	4
1937.....	6504	8	2
1938.....	6105	17	5
1939.....	5106	25	4
1940.....	5835	24	5
1941.....	6148	33	3
1942.....	6340	22	5
1943.....	6175	17	8
1944.....	7452	11	5
Totals.....	118,611	280	78

TABLE II  
SEX INCIDENCE

	All Embolism	Fatal Embolism
Males.....	166	46
Females.....	114	32
	280	78

TABLE III  
AGE INCIDENCE

Age-Group	All Embolism	Fatal Embolism
0-9 yrs.....	0	0
10-19.....	1	0
20-29.....	18	3
30-39.....	57	8
40-49.....	73	15
50-59.....	62	17
60-69.....	46	22
70-79.....	20	10
80-89.....	3	3
	280	78

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TABLE IV  
INCIDENCE OF EMBOLISM AFTER CERTAIN OPERATIONS

Operation	Number	All Embolism	Fatal Embolism	Percentage Fatal Embolism
Hernia.....	7887	42	6	0.076
Fractures.....	5199	39	12	0.23
Hysterectomy.....	3833	35	6	0.16
Cholecystectomy.....	2883	24	6	0.21
Prostatectomy.....	756	19	8	1.06
Appendicectomy.....	5450	15	4	0.075
Stomach operations.....	858	13	7	0.82
Colon operations.....	448	8	3	0.67
Breast operations.....	1461	4	3	0.20
Brain operations.....	810	2	1	0.12
Miscellaneous urology.....		13	6	
Miscellaneous trauma.....		12	1	
Amputations (lower ext.).....		10	3	
Postpartum.....		6	1	
Miscellaneous gynecology.....		6	1	
Miscellaneous orthopedics.....		6	3	
Varicose vein operations.....		6	0	
Ophthalmology.....		3	0	
Phlebitis.....		3	1	
Hemorrhoidectomy.....		2	1	
Miscellaneous.....		12	5	
		280	78	

episodes occurred most frequently in the fifth decade, while fatal embolism was noted most often in the sixties. It is evident that patients above the age of 40 must receive special attention.

*Type of Operation.*—Table IV presents a tabulation indicating the incidence of embolism following certain common operations. It was expected that abdominal operations would show the complication frequently, and head and neck operations not at all. This was the case. Gastric operations and prostatectomy were the worst offenders, showing an incidence of about one in a hundred for fatalities. On the other hand, the operation of thyroidectomy was not accompanied by a proven case of embolism. For cholecystectomy, the incidence is 1:500, for hysterectomy, 1:600, and for hernia and appendicectomy, 1:1300.

*Postoperative Day.*—(Table V): It is interesting to note that there are two peaks of fatal embolism in this table, on the sixth and eleventh days. This would correspond to the time of getting patients up to go home at the end of one or two weeks, respectively. Early ambulation, as advised by Leithauser,<sup>2</sup> and others, should change this tabulation in subsequent years.

*Clinical Symptoms and Signs.*—(Table VI): The cardinal sign of minor embolism is pain in the chest. The patient may say that it is in his back or "kidney," but sooner or later it is evident that there is pleural irritation on one side or the other. The ratio of pain on the right side to that on the left was 5:3. Hemoptysis, physical signs and positive roentgenographic findings were each present in about half of the cases. A friction rub was noted in a third and an effusion was demonstrated roentgenographically or by thoracentesis in a fifth of the cases.

*Circumstances of Fatal Episodes.*—The possibility of carrying out the Trendelenburg operation of pulmonary embolectomy has been the subject of much speculation. There is no report of a successful case in this country, and such an authority as Graham<sup>3</sup> has stated that he is doubtful if the operation is ever indicated. Nevertheless, for those who may be interested, the interval before death and the time of day of the episode in each case are tabulated. (Tables VII and VIII.) Almost half of the cases died in less than ten

TABLE V  
POSTOPERATIVE DAY OF EPISODE

Day	Nonfatal	Fatal
1.....	3	2
2.....	2	0
3.....	9	4
4.....	14	3
5.....	16	3
6.....	18	9
7.....	16	1
8.....	15	2
9.....	22	3
10.....	13	0
11.....	20	10
12.....	16	2
13.....	12	2
14.....	25	5
15-19.....	40	14
20-29.....	27	4
30-.....	12	14
	<hr/> 280	<hr/> 78

TABLE VI  
SYMPTOMS AND SIGNS IN 222 NONFATAL EPISODES

	Number	Per Cent
Pain in:		
Right chest.....	127	58
Left chest.....	74	33
"Chest".....	3	1
Epigastric.....	3	1
Low back.....	2	1
Substernal.....	4	2
Unrecorded.....	9	4
	<hr/> 222	<hr/> 100%
Hemoptysis.....	97	44
Friction rub.....	68	31
Effusion.....	43	19
Dullness.....	112	54
Positive roentgenogram.....	113	54

minutes, three-fourths died in less than half an hour, and only 10 per cent lived more than an hour. Theoretically, it would be possible to operate upon a fourth of the cases. Less than half of these could have the services of a Staff Surgeon under ordinary circumstances, since 44 of the 78 fatal episodes took place during "off hours."

*Effect of Treatment.*—The possibility of utilizing heparin to prevent

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thrombosis received early consideration at the Henry Ford Hospital. In 1924, Mason<sup>4, 5</sup> used the drug in transfusions, and demonstrated that suitable doses gave protection against the clotting of blood which followed the intravenous injection of cephalin into experimental animals. He stated: "If clinical throm-

TABLE VII  
INTERVAL BEFORE DEATH IN FATAL CASES

	No. of Cases
Less than 5 mins.....	18
5-9 mins.....	16
10-14 mins.....	8
15-29 mins.....	14
30-39 mins.....	13
1-3 hours.....	2
3-12 hours.....	1
12-24 hours.....	1
More than 24 hours.....	1
Not stated.....	4
	<hr/> 78

TABLE VIII  
TIME OF DAY OF FATAL EPISODES

	No. of Cases
<i>"Office Hours"</i>	
9:00 A.M.-12:00 noon.....	13
12:00 noon-3:00 P.M.....	12
3:00 P.M.-6:00 P.M.....	9
	<hr/> 34
<i>"Off Hours"</i>	
6:00 P.M.-9:00 P.M.....	10
9:00 P.M.-12:00 midnight.....	13
12:00 midnight-3:00 A.M.....	7
3:00 A.M.-6:00 A.M.....	8
6:00 A.M.-9:00 A.M.....	6
	<hr/> 44

TABLE IX  
RESULTS OF TREATMENT OF NONFATAL EMBOLISM

Year	Number of Operations	Nonfatal Embolism	Treated Cases			Fatal Embolism	Fatal with Treatment
			Heparin	Dicumarol	Ligation		
1939.....	5106	21	7	—	—	4	0
1940.....	5835	19	15	—	—	5	1
1941.....	6148	30	23	—	—	3	1
1942.....	6340	17	5	7	2	5	0
1943.....	6175	9	—	7	—	8	0
1944.....	7452	6	1	2	3	5	0
	<hr/> 37,056	<hr/> 102	<hr/> 51	<hr/> 16	<hr/> 5	<hr/> 30	<hr/> 2

bosis and embolism are comparable with experimental thrombosis and embolism, the anticoagulant offering so effective protection in one should be of use in the other." Doctor McClure relates that three of his patients were treated with material furnished by Mason, but the crude product available at

that time produced such untoward reactions that its use was discontinued. When purified heparin became available in 1939, it was used extensively in patients showing thrombotic manifestations. This experience has been presented in several reports.<sup>6, 7, 8</sup> Other specific measures to be adopted were dicumarol administration and femoral vein ligation.<sup>9</sup> One group of post-operative patients has received special attention. These are the individuals who have had a nonfatal infarction, thus, indicating the presence of dangerous thrombosis. Twenty of the 78 fatal cases had a previous nonfatal episode. This number added to 202 (number of surviving patients) gives a total of 222 nonfatal episodes. Seventy-two of these received treatment, and two of these died, giving a mortality rate of 2.8 per cent. On the other hand, 18, or 12.1 per cent of the untreated cases, died. At the Mayo Clinic,<sup>10</sup> it was found that 18.5 per cent of patients with pulmonary infarct subsequently had a fatal embolism if no treatment was given. In a group of 63 such patients treated with heparin, there were only two deaths (3.2 per cent).

If treatment is so effective, why does not Table I indicate a decreasing incidence of fatal embolism instead of showing a plateau? This question may be answered by the data presented in Table IX, and a brief analysis of the fatal cases during the past six years.

The 30 fatal cases since 1939 had the following operations: Fracture of the neck of the femur, with or without nailing (five cases), hysterectomy (three cases), partial gastrectomy (three cases), cholecystectomy (five cases), hernia repair (three cases), appendicectomy (three cases), radical mastectomy (two cases), prostatectomy (two cases), partial resection of bladder, abdominoperineal resection of rectum, spinal fusion, and phlebitis (no operation). There was no apparent warning in 25 cases, hence, they received no special treatment. Two of the remaining five cases did receive treatment but died in spite of it; one of these had a partial gastrectomy and the other an operation for perforated appendix. Each had a second and fatal embolism on the second and seventh days, respectively, of heparin therapy. One patient who had had a prostatic resection for carcinoma had a nonfatal infarct and was scheduled for femoral vein ligation. He was inadvertently given an enema in preparation for this operation and expired with massive embolism while expelling it. The mere diagnosis of phlebitis in one patient should have indicated active measures against embolism—femoral vein ligation might have saved him. The fifth and last patient to be accounted for had been operated upon for hernia, and a warning pulmonary infarct had occurred. Although no purified heparin was on the market in this country at that time (1939), arrangements were being made to obtain some from Toronto. However, the patient (a doctor) was opposed to the new and relatively untried treatment and while deliberations were proceeding, a second embolism caused his death.

In retrospect, what could have been done to avert catastrophe in the 25 patients who expired without warning? Routine anticoagulant therapy should be considered. However, even if such treatment gave 100 per cent protection, it would have been necessary to heparinize or dicumarolize 3,900 patients

to prevent the three appendectomy deaths. The hemorrhagic complications in such a series would undoubtedly be notable. The plan is even less attractive when it is remembered that one of the appendectomy cases was lost in spite of heparin treatment. More care in looking for local signs of thrombosis in the legs and carrying out femoral ligation promptly, when indicated, should be of value. In this connection it should be pointed out that the figure of five for femoral vein ligation in Table IX represents only a fraction of those operations which have been performed during the past three years. The cases which had early ligation never had any kind of embolism, and, hence, were not included in the tabulation. However, since dangerous thrombosis can occur without producing signs or symptoms, even the extensive use of femoral vein ligation leaves many patients unprotected. A prophylactic procedure which can be easily applied to all, or nearly all, operations is needed. Early ambulation may be the answer. Many surgeons are getting their patients up on the first day and are noting an absence of embolic complications. If incisions have been properly placed and nonabsorbable suture material has been used, it should be perfectly safe for patients who have had appendectomy, hernia repair, cholecystectomy, gastrectomy or hysterectomy to be up on the afternoon of operation. It will be noted that 17 of the 25 cases under discussion had the operations just enumerated. It may be that fractures of the femoral neck, prostatectomies, radical mastectomies, spinal fusion and resections of the rectum will require some modification of the early ambulation program. It is probable that even these patients can be protected by appropriate means.

#### SUMMARY AND CONCLUSION

A study has been made of the fatal and nonfatal embolic complications which occurred in a series of over 100,000 operations. Predisposing factors have been noted with regard to age, sex and the type of operation. Since the adoption of anticoagulant therapy and prophylactic femoral vein ligation, there has been a very low mortality rate in cases selected for treatment. However, these measures have not prevented a number of sudden and unexpected fatal embolisms. Early ambulation offers the most promise as a preventive measure easily applicable to the majority of surgical patients.

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# CONGENITAL CYSTIC LUNG

SUCCESSFUL PNEUMONECTOMY IN A THREE-WEEK-OLD BABY

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CYSTIC DISEASE OF THE LUNG occasionally appears as a consequence of inflammatory reactions. Cicatricial tissue around bronchi, bronchioles, and alveolar ducts can produce obstructive emphysema of a bullous type, so that cavernous spaces of considerable size develop in the pulmonary parenchyma. When examined roentgenologically, such a lung will show the mottled and increased density of pulmonary infection and, in addition, will indicate the interspersed cystic areas. If the patient is seen for the first time at this early stage, it is impossible to determine whether the cysts are of congenital origin and the infection superimposed thereon, or whether the cysts are the product of the pneumonitis. If such a patient survives for a protracted period—as is frequently the case—the more active portions of the inflammation can disappear and give little or no shadow in the roentgenogram, whereas some persistent scarring can maintain the cystic process. Hence, at a late stage the postinfectious origin of the cysts can be appreciated only if a history of pneumonitis is obtainable or if the lung comes to microscopic examination by a competent pathologist.

Lung cysts may also be of congenital origin, though these are probably less common than the acquired form. There have been adequate descriptions of specimens which have been removed surgically or which have been found at autopsy. Such an abnormality of the lung may arise as a solitary, globular structure from an accessory bronchial bud and thus appear as a pedunculated, balloon-like affair, situated between pulmonary lobes or else projecting in front of or behind the lung root. More frequently, cysts develop within the lung substance and under such circumstances they are quite apt to be multiple. The lining membrane is composed of a bronchial epithelium, the individual cells of which are mucous-secreting, ciliated, and columnar in type. This histologic feature positively identifies the cyst as being congenital in origin. Beneath the lining membrane there may be a thin layer of smooth muscle and possibly bits of irregularly placed cartilage. There may or may not be some superimposed infection. Congenital lung cysts are occasionally bilateral, but fortunately they are more often limited to one lung.

Some congenital cysts of the lung have little clinical significance. If they do not become infected and if they are small enough to leave the physiology of the lung undisturbed, their existence is of little more than academic interest. Their presence may be incidentally discovered by roentgenologic examination of the chest; they can persist for many years with no ill effects on the patient's

health. However, not all congenital cysts run a benign course; they may give rise to complications, principally of two sorts. In the first, infection of the cyst wall or suppuration within its lumen may be extensive and serious. In the second, the cyst (or cysts) is connected to the respiratory tract by a relatively small or angulated passageway, so that air enters and becomes entrapped within the cavity. Thus, a positive pressure can be built up within the cyst (or cysts) so that the structure becomes greatly distended and compresses adjacent lung tissue, and possibly displaces the mediastinal organs to the opposite side of the chest. Hence, it is obvious that respiratory distress can be extreme, and indeed the situation may be incompatible with life unless some form of relief is promptly instituted.

Respiratory embarrassment from increased tension within lung cysts could be relieved in one of several ways:

1. A needle can be passed through the chest wall and into the cyst cavity—permitting quick withdrawal of entrapped air. Resulting improvement in the patient's condition is apt to be immediate and dramatic, but is only temporary since air will almost certainly reaccumulate. Furthermore, a puncture of the cyst wall is prone to allow subsequent escape of air from the cyst into the pleural space—thus, complicating the general picture in the ensuing few hours. Without doubt, aspiration of a distended cyst may be a life-saving procedure, but it should be done only with a very fine-bore needle and probably should be employed only as a temporizing measure while preparing for a more adequate treatment of the lesion.

2. A trocar can be introduced through the chest wall and into the cyst so that a catheter may be threaded into it for establishment of prolonged aspiration. In this form of treatment, it would be preferable to employ a small mushroom catheter, so that its bulbous end could be pulled up against the inside of the cyst wall and prevent escape of air into the pleural space. Constant application of suction to the catheter should keep the cyst completely collapsed—even for a protracted period—and this should be of value while preparing for more extensive surgery. It is tempting to think that congenital cysts might be sclerosed by introduction of appropriate fluids through a catheter, but the communication with a bronchus would obviously preclude such therapy.

3. Marsupialization of the cyst onto the chest wall and destruction of its lining membrane by curettage, cauterization, or packing has many points in its favor as a method of treatment. However, an external opening introduces a considerable hazard, because infection might gain entrance to the regional lung substance and this might be difficult to control. The greatest objection to the method is the fact that congenital lung cysts are prone to be multiple and, hence, the treatment of one cyst—even though successful in obtaining its obliteration—is apt to be followed by the subsequent formation of additional cysts in the nearby lung tissue. Hence, marsupialization should be practiced only when the surgeon is quite sure that he is dealing with a solitary cyst.

4. Enucleation of a pulmonary cyst, or removal of pulmonary tissue containing it, is by far the treatment of choice. The extent of the cystic disease will determine how extensive a resection of lung substance will be required. Local resection, lobectomy, or even pneumonectomy may be necessary. In general, as much lung tissue as possible should be saved, but an adequate margin must be removed to insure complete removal of all abnormal structures.

In the case herein reported, a left total pneumonectomy was performed for respiratory distress resulting from congenital cystic disease of the lung. Though the baby was but 23 days of age, and weighed only 6 lbs. 4 oz. (2.8 kilos), the operation was tolerated in a surprisingly satisfactory manner. Likewise, the postoperative recovery was prompt, uncomplicated, and most gratifying.

**Case Report.**—W. W. was a three-week-old, male infant, who entered the hospital, December 7, 1944, having been referred by Dr. Eli C. Rodman. On the fourth day of life the child was noted to be breathing in an abnormal and slightly labored way, but there was no cyanosis. During the following days the respiratory rate was known to be definitely elevated, and this symptom gradually increased in severity. On the day of hospitalization dyspnea had become quite pronounced, and the child was moderately cyanotic. On examination by the family physician, the color was found to be poor, the breathing was very rapid, and the pulse was quite fast. Immediate hospitalization was recommended.

*Physical examination* showed the following points: The weight was 6 lbs. 4 oz. The temperature was normal. The baby tended to lie with his head thrown back, and was obviously using the accessory muscles of respiration. The alae nasi dilated during respiratory efforts. The color was fairly good, except during periods of straining and crying when there was moderate cyanosis. The respiratory rate was counted at 110-120, the pulse was 140 per minute. There was no percussible area of cardiac dullness on the left. Lateral to the right lower border of the sternum there was dullness, which presumably represented a dextro-position of the heart. This observation coincided with the finding of normal cardiac sounds to the right of the sternum and only very faint sounds to the left of the sternum. The respiratory excursion of the left side of the chest was diminished as compared to that of the right. There was slight intercostal and supra-clavicular retraction over the right side of the chest. There was increased resonance over the left lung anteriorly and posteriorly, with apparently normal resonance over the right lung field. The breath sounds over the entire left lung were extremely faint. Over the right lung the breath sounds were of normal quality.

*Roentgenologic examination* of the chest showed the left hemithorax to be increased in volume, with depression of the left dome of the diaphragm. Within the left lung substance there appeared to be a large, air-containing sac with a thin and sharply outlined, smooth wall (Fig. 1). This cystic structure occupied a large part of the left hemithorax, but there was some compressed lung tissue at the left base and at the left apex. Some of the left lung appeared to be herniated across the midline of the chest. The mediastinum was markedly shifted toward the right, the heart was in a dextro-position, and the right lung was considerably compressed. The findings suggested a cavity within the left lung which was filled with air under positive pressure. In order to rule out a left diaphragmatic hernia, a swallow of barium was given and appropriate films excluded any possibility of such a malformation.

*Course:* Because of the marked respiratory distress and the intermittent cyanosis, the child was placed in an oxygen tent, and carefully observed for a period of 24 hours. The respirations were slightly improved with the administration of oxygen and diminished to 90-100 per minute. For the most part, the cyanosis was fairly well-controlled, though

at times the baby was dusky, particularly during episodes of squirming, straining or crying. It became clear that air had become entrapped under positive pressure within the cyst of the left lung and that some form of mechanical relief was essential. Needling of the cyst was avoided, because of the belief that its beneficial effects would be temporary, and that it would be accompanied by the danger of allowing air to escape into the pleural cavity, which might thus complicate the general situation.



FIG. 1—Preoperative roentgenogram of the chest, showing large cyst in the left lung, marked displacement of the heart to the patient's right, and compression of the right lung. (Cyst indicated by arrows)

Operation was decided upon, with three general plans of therapy in mind: 1. If the cyst should be found arising from a separate bronchial stalk and lie outside of pulmonary tissue, amputation of it should be relatively simple and effectual. 2. If the cyst lay within one lobe of the lung, this entire lobe could be sacrificed and lobectomy would be the method of choice. 3. If the cyst lay within the left lung so that it involved its hilum, then the entire lung would be removed. It was definitely decided before operation that no attempt would be made to peel out a lung cyst which might reside within pulmonary substance, since such a dissection would lead to extensive hemorrhage or would be followed by multiple bronchial fistulae, empyema, or uncontrollable pneumothorax. It was our conviction that any such dissection of a cyst out of lung tissue would entail an operative procedure of too great magnitude for a tiny and seriously ill baby.

*Operation:* With a tightly-fitting face mask, and without a laryngeal tube, cyclopropane anesthesia was induced, and was tolerated extremely well. A left anterolateral thoracotomy was performed in the fourth interspace. The opening of the chest was extremely simple; it was not necessary to remove any rib or to cut the costal cartilages, since the bony and cartilaginous structures in the infant were so soft and yielding that the insertion of a self-retaining retractor permitted an adequate exposure. The normal lung contour was altered by the presence within it of a golf ball-sized, air-filled and tense cyst which lay largely within the lower part of the upper lobe but which extended well into the hilum of the lung. The left lower lobe was compressed and atelectatic, as was the apex of the upper lobe. Situated around the periphery of the main cyst, particularly toward its superior border, there were several smaller cysts, 2-4 mm. in diameter. Two things seemed evident: First, that the main cyst was so large and extended so far into the root of the lung that it would be impossible to perform an upper lobectomy without damaging the root of the lower lobe. Second, that any removal of the main cyst (even though this might be feasible) would still leave some of the tiny cysts in adjacent lung tissue which might conceivably develop at a subsequent time and give further trouble. Total pneumonectomy was, therefore, decided upon. The cyst was deflated with an aspirating needle; this greatly facilitated the subsequent steps. There were no pleural adhesions over any part of the lung surface. The pneumonectomy was performed with ease since there was no inflammatory reaction in the root of the lung, and the dissection could be carried out quickly. Individually, arteries and veins were doubly tied with No. 00000 Deknata silk and were divided. The left main bronchus was doubly clamped and then divided between these instruments. The bronchial stump was sewed over-and-over with a continuous No. 00000 Deknata silk which was carried on a small, atraumatic needle; this gave a satisfactory and tight closure. Flaps of parietal pleura were now mobilized anteriorly and posteriorly and brought together with interrupted fine silk sutures so as to cover over and completely bury the bronchial stump within the mediastinum. A small urethral catheter was placed within the pleural cavity and the chest was closed with continuous No. 000 chromic catgut to the intercostal muscles and continuous No. 0000 chromic catgut to the severed pectoral muscles. Interrupted silk sutures were placed in the subcutaneous tissues and skin. Just before the last cutaneous sutures were placed, suction was applied to the indwelling catheter and all air was sucked out of the left pleural cavity. The catheter was then quickly withdrawn and the remainder of the skin was tightly closed. The infant stood this procedure quite well, but was given a transfusion of 40 cc. of citrated blood at its conclusion.

*Postoperative Course:* Following operation the child was replaced in an oxygen tent for 24 hours. On the evening of the day of operation, sips of saline and glucose were given by mouth, and were retained. On the following day oral feedings were started, providing about half of the normal caloric and fluid requirements. At the end of 48 hours the child was taking full feedings by mouth without any difficulty. The color was good throughout the postoperative course, except for a period of several hours on the sixth day when the oxygen tent was temporarily resumed. The general vigor of the baby during the postoperative course was extraordinary. The temperature rose to 101° F. (rectal) 24 hours after operation, but gradually subsided to normal by the fifth day. The respiratory rate was elevated to 60 or 70 per minute, but gradually diminished during the following ten days to a level of 50 or 60, with occasional peaks to 65. Following operation the baby was given intramuscular injections of penicillin, totaling 32,000 units per 24 hours, for seven days. The chest wound healed *per primam* (Fig. 2). There was no evidence of empyema or bronchial fistula at any time. A moderate amount of fluid accumulated in the left pleural space, but this was not sufficient to require tapping of the chest. The weight-gain was satisfactory and progressive. The weight upon admission had been 6 lbs. 4 oz.; it rapidly increased to 7 lbs. 6 oz. at the time of hospital discharge, on the fifteenth day.

For the first few days after operation the superficial veins over the right side of the scalp and the right side of the neck were distinctly distended when compared to their preoperative condition and to the postoperative condition of the left side of the head, neck, and shoulder. Presumably the postoperative shift in the mediastinum had *angulated and partially obstructed the veins as they entered the right side of the upper thorax*. This superficial venous congestion gradually diminished, and by the end of six days had entirely disappeared.



FIG. 2.—Photograph of baby on tenth postoperative day, showing primary healing of chest wound.

During the seven months that the baby has been followed since hospital discharge, there has been no evidence of embarrassment by loss of the left lung. The child's color has constantly remained good; the respirations have been quiet and unlabored. The baby feeds normally and appears to be a bright, active, and normally developing infant. At six months of age the weight was 15 pounds. Figure 3 shows the excellent general condition of the child at that time. Repeated examinations since operation have shown the heart well out to the left side of the chest and the apex beat can be felt and heard in the left axilla. Roentgenologic examinations have shown the mediastinum shifted to the left, so that the right lung has been satisfactorily aerated. Films have shown some fluid in the left pleural space, which has gradually disappeared over the course of a few months. Figure 4 indicates the roentgenologic findings six months after operation. Because of fear that deformity might follow in the chest of such a young child after a complete pneumonectomy, particular attention has been paid to the development of the thoracic cage. The respiratory movements have obviously been more marked on the

## CONGENITAL CYSTIC LUNG

right than on the left, but the thorax appears to be reasonably symmetrical and there is no important scoliosis of the spine.

*Pathologic Examination.*—Dr. Sidney Farber and Dr. James Arey: The lung contained an almost spherical cyst, approximately 5 cm. in diameter, which replaced most of the left upper lobe and which greatly compressed the lower lobe. Scattered around the periphery of this were multiple small cysts, each a millimeter or two in diameter. After fixation in formalin, the lung was sectioned and the general findings indicated in



FIG. 3.—Photograph of baby six months after operation. There is no apparent deformity or asymmetry of the chest.

Figure 5 were noted. The main cyst was lined by a thin, but rather tough layer, which was thrown up into a few low trabeculae. Several tiny, pinpoint openings led out of the main cyst into some of the smaller cavities previously described in the adjacent upper lobe substance. No cysts were found in any part of the lower lobe. A tiny hairpin probe could be passed by a tortuous route from the main cyst into the upper lobe bronchus.

Microscopically, the wall of the large cyst was found to be lined by ciliated, columnar epithelium, supported on an abundant, loose, connective tissue base (Fig. 6). Surrounding this were scattered bundles of nonstriated muscle. In some areas, islands of cartilage could be demonstrated in the wall of the major cyst. In a few places, some mucous-secreting glands lay deep in the wall and were scattered through and outside of the smooth muscle layer. Some sections showed the tiny, secondary cysts around the periphery





FIG. 4.—Roentgenogram, six months after operation. The heart is drawn to the left side of the chest. The upper part of the right lung has ballooned over into the apex of the left pleural cavity.



FIG. 5.—Photograph of sectioned lung, with large, central, congenital cyst.

## CONGENITAL CYSTIC LUNG

of the main cavity, from which they were separated by the smooth muscle layer. These were, likewise, lined by a ciliated, columnar epithelium, and in some instances a direct communication could be demonstrated with the large main cyst (Fig. 6A). Other sections taken from the upper lobe showed additional small, congenital cysts, the openings of which could not be found. This cystic change through the pulmonary tissue was much more extensive than had been suggested by the gross appearances of the specimen. Some of the sections showed mild edema or extravasation of red cells into alveolar tissue of the surrounding lung, which were probably secondary to the trauma of oper-

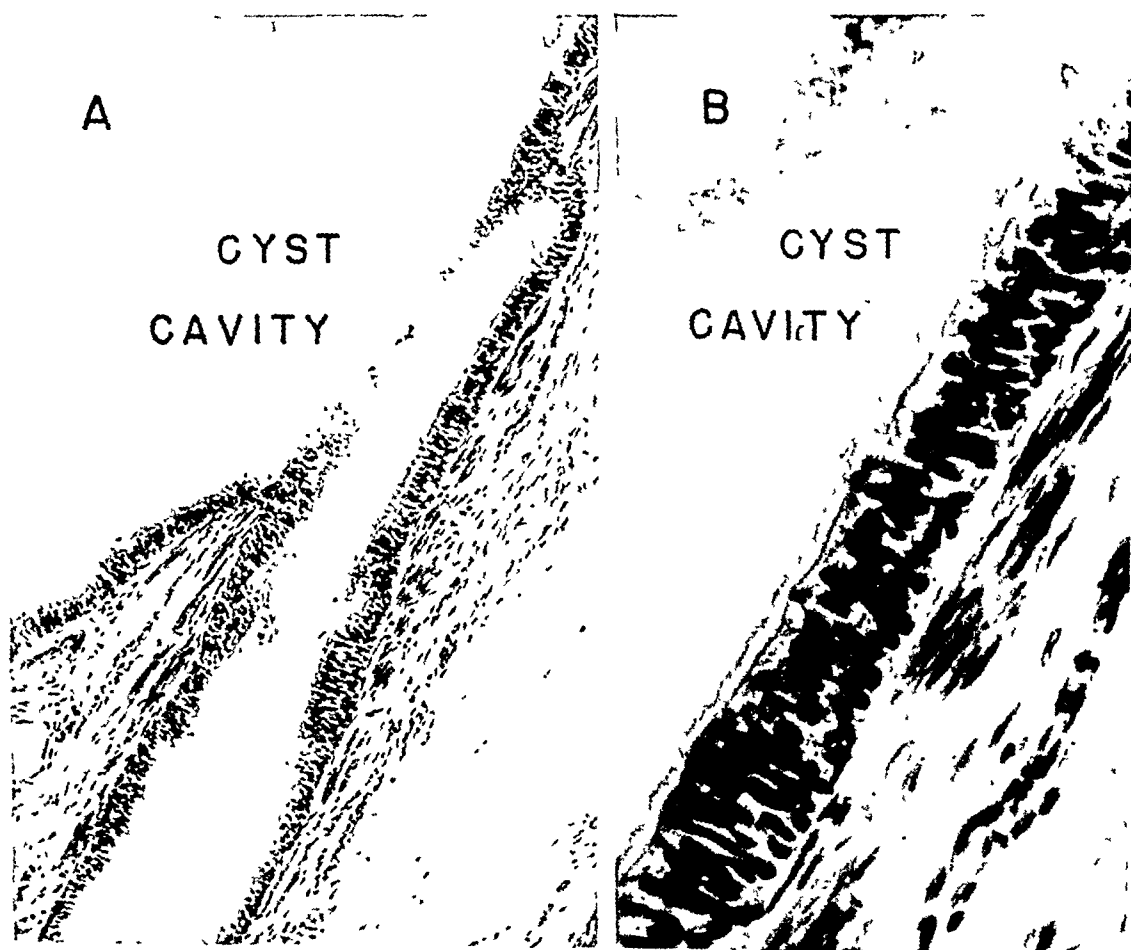


FIG 6.—A. Low power photomicrograph showing cyst lining and the opening to a secondary cyst.  
B. Higher magnification, showing ciliated columnar epithelium, from the main cyst wall.

ation. There was no important inflammatory change in any of the material which was studied.

### SUMMARY

A brief report is made of a three-week-old baby with congenital cystic disease of the left lung, who was treated by total pneumonectomy. In spite of the child's small size, he withstood the operation in a very satisfactory manner and has had an uncomplicated postoperative course.

# DELAYED INTERNAL FIXATION OF COMPOUND BATTLE FRACTURES IN THE MEDITERRANEAN THEATER OF OPERATIONS

CASE HISTORIES WITH ILLUSTRATIONS  
A FOLLOW-UP STUDY IN THE ZONE OF INTERIOR

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## PART II

THE CASE REPORTS are presented to illustrate the classifications of indications and results as they are compiled in the tables of data. While the reports have been made brief, the principles of reparative surgery of compound fractures including those for the use of delayed internal fixation are illustrated frequently.

### Case 1\* (*see Plate I*)

*Indication—Obligate-1:* Bone loss producing a segmental defect.

*Result—A:* The fracture united and the wounds healed, without sequestration or removal of metal.

*Diagnosis:* 1. Fracture, compound, comminuted right humerus lower part of mid-shaft, with segmental loss of bone. 2. Laceration of median and ulnar nerves.

*Wounded:* October 20, 1944, missile—not recorded.

*Reparative Surgery:* On November 1, 1944, additional devitalized tissue including several totally loose bone fragments was excised. A manual effort to reduce the fracture and hold it by a spica encasement was unsuccessful.

On November 12, through the unsutured compounding wound, the ends of each fragment were squared to maximize the surface for bone contact, which was achieved by fixation with three wire loops. The resultant shortening was about two inches. A pressure dressing held soft-parts partially over bone but suture was not performed.

On November 20 the wound was partially sutured and a skin flap was rotated so as to cover all denuded bone. He was evacuated to the Zone of Interior in early December, in a "hanging cast."

*Zone of Interior Record:* On arrival, all bone was covered, but there was an unhealed granulating area. The wound healed and the fracture united promptly without sequestration or removal of metal.

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\* This patient was managed by Major Herbert W. Harris.

PLATE I

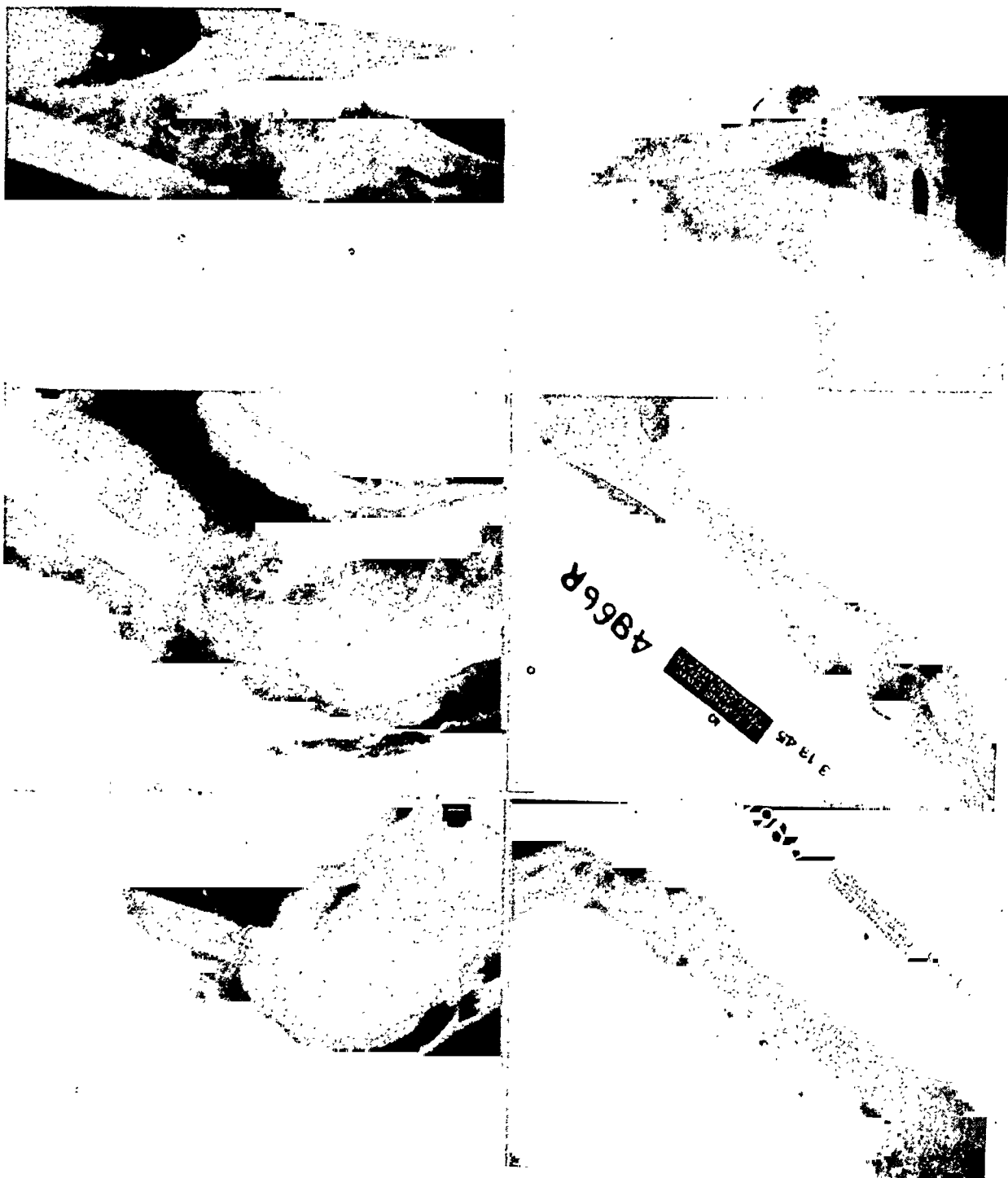


PLATE I.—Case 1: A. A. P. view on admission to Base Hospital. Note bone loss and defect.  
B. Lateral view on admission to Base Hospital. Note bone loss and defect.  
C. A. P. view after fixation.  
D. Lateral view after fixation.  
E. A. P. view after bony union and wound healing, without sequestration or removal of metal.  
F. Lateral view after bony union and wound healing, without sequestration or removal of metal.

**Case 2\* (see Plate II)**

*Indication—Obligate-1:* Bone loss creating a segmental defect of bone, without contact of fragments.

*Result—E:* The fracture did not unite but the wound healed, without sequestration or removal of metal.

*Diagnosis:* 1. Fracture, compound, comminuted right humerus, with loss of bone.  
2. Laceration of radial nerve.

*Wounded:* May 6, 1944, by high explosive shell fragments.

*Reparative Surgery:* About May 14th a septic compounding wound was revised, excising the residual dead tissue. A segmental bone defect was present. The fragments were approximated by two wire loops. The severed radial nerve was located, approximated by a single suture, and transplanted to a bed in healthy muscle. Muscle was sutured so as to cover all denuded bone and the nerve. The skin was partially closed. The wounds healed. On July 13th he was evacuated to the Zone of Interior in a shoulder spica.

*Zone of Interior Record:* On admission, all wounds were healed. The fracture did not unite. On January 23, 1945, bone grafting of the humerus and definitive suture of the radial nerve were performed. The wire loops were removed at that time.

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\* This patient was managed by Major Joe M. Parker and Lt. Col. Henry G. Schwartz.

## COMPOUND BATTLE FRACTURES

### PLATE II

A



B



C

PLATE II.—Case 2: A. A. P. view—15 July, 1944—in the overseas hospital.  
B. Lateral view—15 July, 1944—in the overseas hospital.  
C. Lateral view—19 January, 1945—showing the nonunion.

**Case 3\* (see Plate III)**

*Indication—Obligate-1 and 2:* Distraction and failure to achieve reduction.

*Result—B:* Fractures united and after removal of sequestra and metal the wounds healed.

*Diagnosis:* Fracture, compound, comminuted distal third, left radius and ulna.

*Wounded:* May 31, 1944, by high explosive shell fragments.

*Reparative Surgery:* Partial wound closure and manipulative reduction, about June 10, were not successful. Necrotic bone presented itself in the septic wound. On August 12, 1944, the necrotic bone ends were excised back to bleeding bone, the fragments of each bone were approximated and fixed in reduction by plates. The resultant shortening from bone loss and death of bone was about three inches. The wounds were closed with drainage.

*Zone of Interior Record:* On admission, October 22, 1944, the wounds were draining but the fracture site was stable and was uniting. On December 7, 1944, sequestra and the metal were removed, after which the wounds healed promptly. Plastic tendon surgery was planned.

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\* This patient was managed by Major Allen Collom.

# COMPOUND BATTLE FRACTURES

## PLATE III

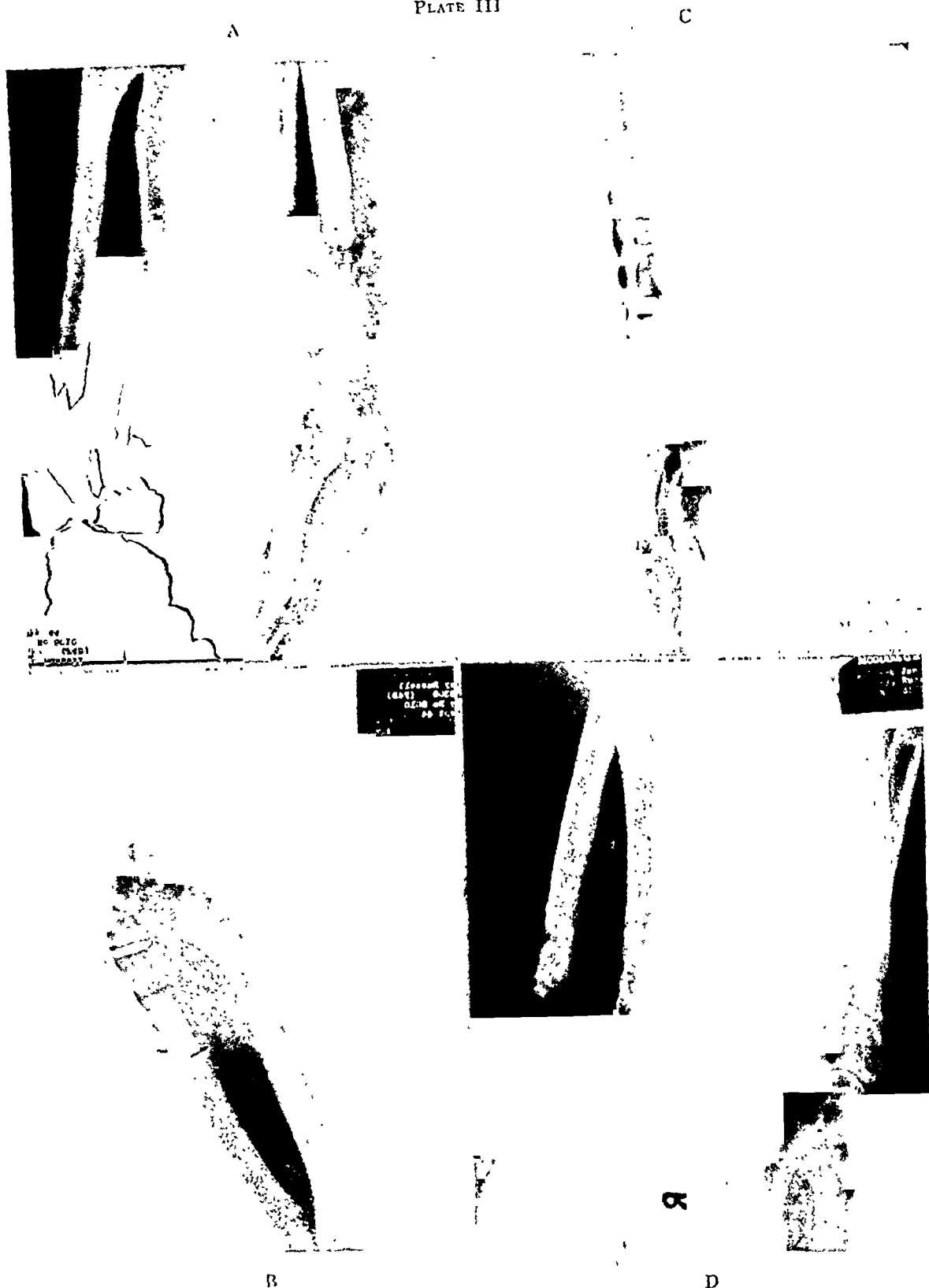


PLATE III.—Case 3: A. A. P. and lateral views, 14 July, 1944—five weeks after plating.  
B. A. P. view—18 September, 1944—five weeks after plating.  
C. Lateral view—18 September, 1944—five weeks after plating.  
D. A. P. and lateral views, 6 January, 1945. The fractures are united and the wounds are healed.



**Case 4\*** (*see Plate IV*)

*Indication—Obligate-2 and 1:* Failure to obtain reduction by other measures (traction) plus persistent distraction. (Fixation in presence of established sepsis.)

*Result—A:* The fracture united in anatomic alignment, and the wounds healed without sequestration or removal of metal.

*Diagnosis:* 1. Fracture, compound, comminuted left femur midthird. 2. F. C. C. left patella with septic knee joint (not here considered).

*Wounded:* February 16, 1944, by multiple high explosive shell fragments.

*Base Hospital Record:* On admission, February 20, all wounds were septic. Additional devitalized tissue was excised, the wounds were left open, femoral skeletal traction was instituted. The fracture distracted and sepsis continued. From February 20 until March 14 he received 3,000 cc. of whole blood.

*Reparative Surgery:* On March 15 (he received 2,000 cc. of blood that day) fascial plane and fracture site abscesses were drained, totally loose bone fragments were removed and the fracture was stabilized in reduction by a long bone plate. Sufficient wound closure was done to cover all exposed bone. Six days later additional closure and appropriate knee joint surgery were performed. There was intermittent drainage from the most proximal dependent portion of the drainage incision. He was evacuated to the Zone of Interior in May.

*Zone of Interior Record:* Following admission, considerable efforts were made to restore motion to the formerly septic knee. There was recurrent drainage from the wound for some weeks but thereafter the wound remained healed until November 30, when the scar was resected and, at the same time, the metal was removed. Some granulating tissue was curetted. Primary closure of the wound was successful. Brace-protected weight-bearing was instituted for several months. At present he walks with full weight-bearing, and all wounds are healed solidly.

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\* This patient was managed by Major Joseph Godfrey and Captain Russell Erickson.

# COMPOUND BATTLE FRACTURES

PLATE IV

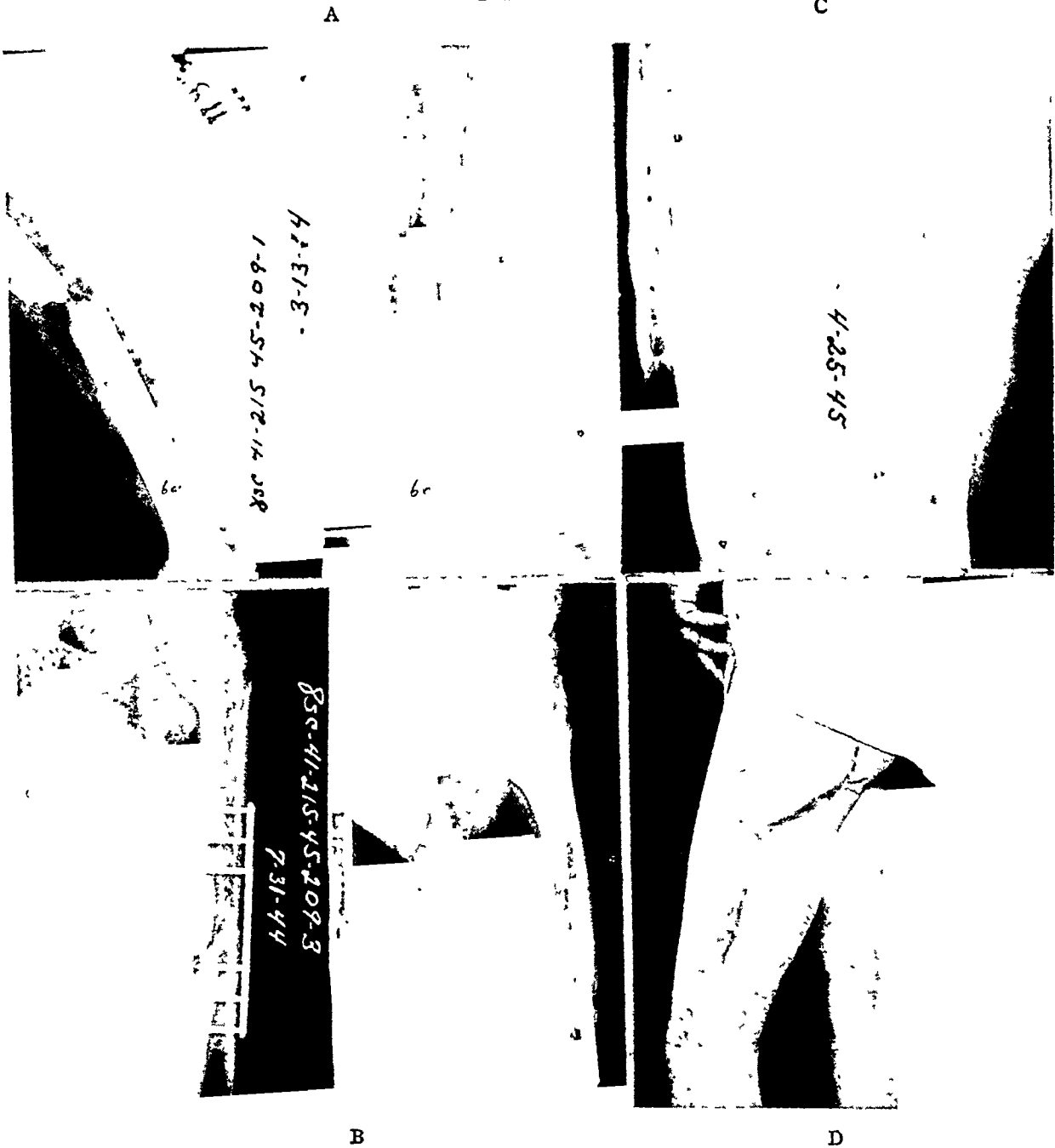


PLATE IV.—Case 4: A. A. P. and lateral views on March 13th, before reparative surgery, revealing the distracted fracture and gas abscesses in the fracture site and adjacent fascial plane.  
B. The united fracture in the Zone of Interior Hospital—31 July.  
C. The united fracture in excellent alignment, with metal removed—April, 1945.  
D. The healed wounds, April, 1945.

**Case 5** (*see Plate V*)

*Indication—Obligate-2:* Failure to achieve reduction by other measures—(established sepsis).

*Result—B:* The fracture united and following removal of metal and sequestra the wounds healed. Late refracture.

*Diagnosis:* 1. Fracture, compound, comminuted left femur lower third (septic).  
2. Sepsis (low grade) left knee joint (not here considered).

*Wounded:* February 20, 1944, by high explosive shell fragments.

*Base Hospital Record:* On February 25 skeletal traction utilizing a wire in the tibial tubercle was instituted. The wounds were purulent at that time. Several incisions for drainage were made including one on the lateral side of the suprapatellar pouch. Pus pocketed in the proximal portion of the posterolateral fascial plane of the thigh.

*Reparative Surgery:* On March 31, the posterolateral plane was incised, draining the abscess and the fracture site. Pus which had tracked up the inner side of the thigh anterior to the adductor magnus was drained by an incision medially. There was no union of the fracture. The extremity was returned to skeletal traction.

PLATE V

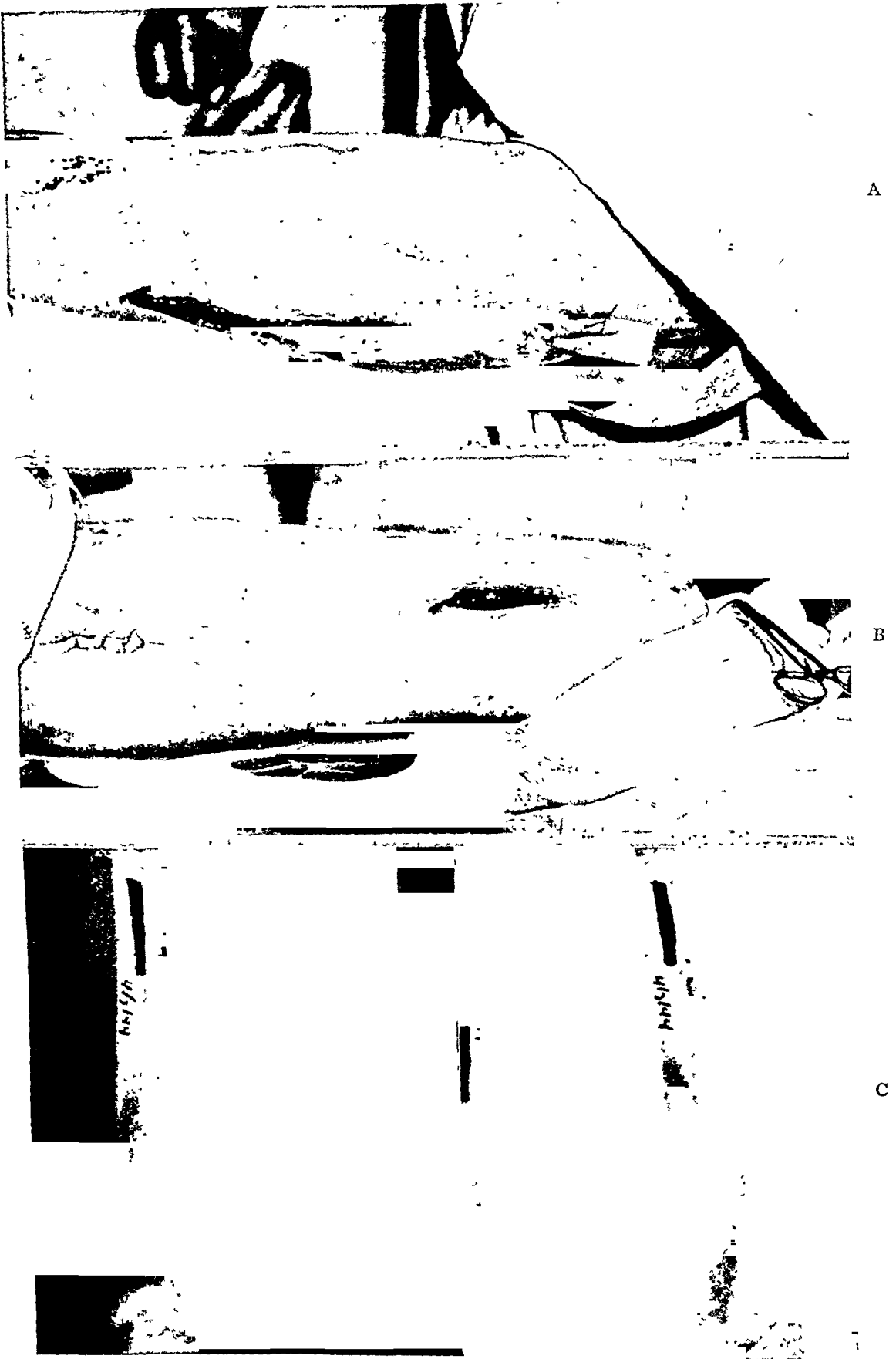


PLATE V.—Case 5: A. The compounding wound, laterally, in the distal third and the drainage incision on 31 March.  
 B. The compounding wound, medially. A drain emerges from an incision at the extreme left hand edge, 31 March.  
 C. The unreduced fracture, 3 April.

**Case 5\*** (*Continued*) (*see Plate V Cont'd*)

On April 6 the fracture was stabilized in reduction by four screws. At the same time the septic knee was cleaned of all necrotic cartilage (including the entire patella), irrigated and closed. The wounds were closed with drainage. There was moderate drainage from all wounds for several weeks but only granulating areas remained when a hip spica was applied on May 11 for evacuation to the Zone of Interior.

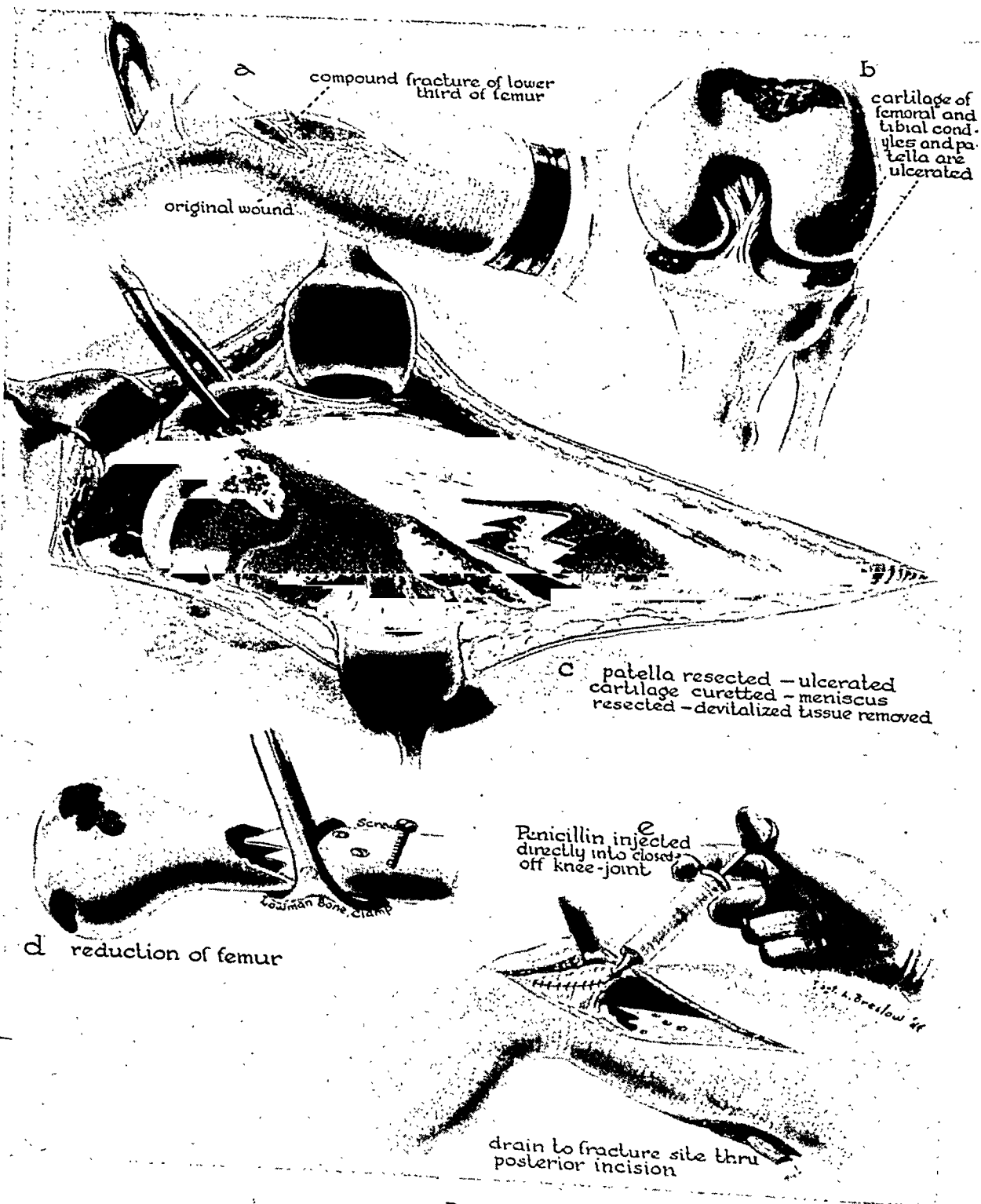
*Zone of Interior Record:* On admission, June 22, there was some drainage medially from the fracture site. On August 24 two sequestra and the screws were removed. The fracture was united but there was a defect in the anterior portion resulting from the bone loss at wounding. The wound healed promptly. In late December, the patient fell, sustaining an incomplete fracture across the site of bone loss. A long leg plaster was applied and he was sent home on furlough. He again fell, completing and displacing the fracture. When observed in March, 1945, the refracture, which is not in the plane of the original fracture, had not been reduced by skeletal traction. There was ten degrees of active knee motion.

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\* This patient was managed overseas by Major Joe M. Parker and Captain Richard Crouch.

# COMPOUND BATTLE FRACTURES

PLATE V—(Continued)



D. Artist's conception of the surgery on 6 April.

PLATE V--(Continued)

E

F



G

- E. The almost healed lateral wounds, 3 May.  
F. The almost healed medial wounds, 3 May.  
G. A. P. view—27 May—before evacuation.



PLATE V. (Continued)—Case 5·H Lateral view—27 May—before evacuation  
 I. A. P. view. The united fracture after removal of sequestra and metal.  
 J. Lateral view. The united fracture after removal of sequestra and metal.  
 K. A. P. view of displaced refracture, February, 1945. Note transverse plane of fracture in contrast to original obliquity.  
 L. Lateral view after refracture, February, 1945. Note refracture point of original bone loss  
 M. Healed medial wounds, March, 1945  
 N. Healed lateral wounds, March, 1945. (The dark area is a recent superficial abrasion of old scar). The range of active knee motion, March, 1945.



**Case 6\* (see Plate VI)**

*Indication—Obligate-2:* Failure to achieve reduction by other measures.

*Result—C:* The fracture is united solidly in excellent alignment, but the wound is unhealed (metal and an obvious sequestrum (roentgenographically) remain *in situ*).

*Diagnosis:* Fracture, compound, oblique, right femur upper third.

*Wounded:* October 2, 1944, by a high explosive shell fragment.

*Reparative Surgery:* Reparative surgery was delayed because of a large volume of casualties reaching this Base Hospital, located only a relatively few miles behind the fighting. Many required both initial and reparative surgery.

On October 21, 19 days after wounding, a wire was inserted through the lower femur. The fracture site was exposed by gentle retraction. The fragments were overriding about 1.5 inches, with interposed muscle. Manual skeletal traction established that reduction by balanced skeletal traction was quite doubtful. (Therefore, this case is classed as Obligate-2.) Through a posterolateral operative approach, the femoral fragments were freed and reduced with difficulty, and were stabilized in reduction by three screws. The compounding wound edges were excised. Neither wound was sutured. The extremity was placed in skeletal traction. On October 26, 1944, five days later, the patient was returned to surgery. Old blood clot and some tissue debris were cleaned from the wounds. Each wound was partially closed with separate drainage. The drains were removed five days later. Both wounds healed but, later, drainage recurred from the lateral wound. He was evacuated to the Zone of Interior in January, 1945.

*Zone of Interior Record:* Drainage has persisted from the old compounding wound, but the fracture united solidly, in good alignment. Roentgenograms, made in May, 1945, reveal an obvious sequestrum and absorption about the two screws. Following their removal, sound wound healing and an excellent end-result are anticipated.

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\* This patient was managed by Lt. Col. Roderick Begg and Capt. Edward Manning.

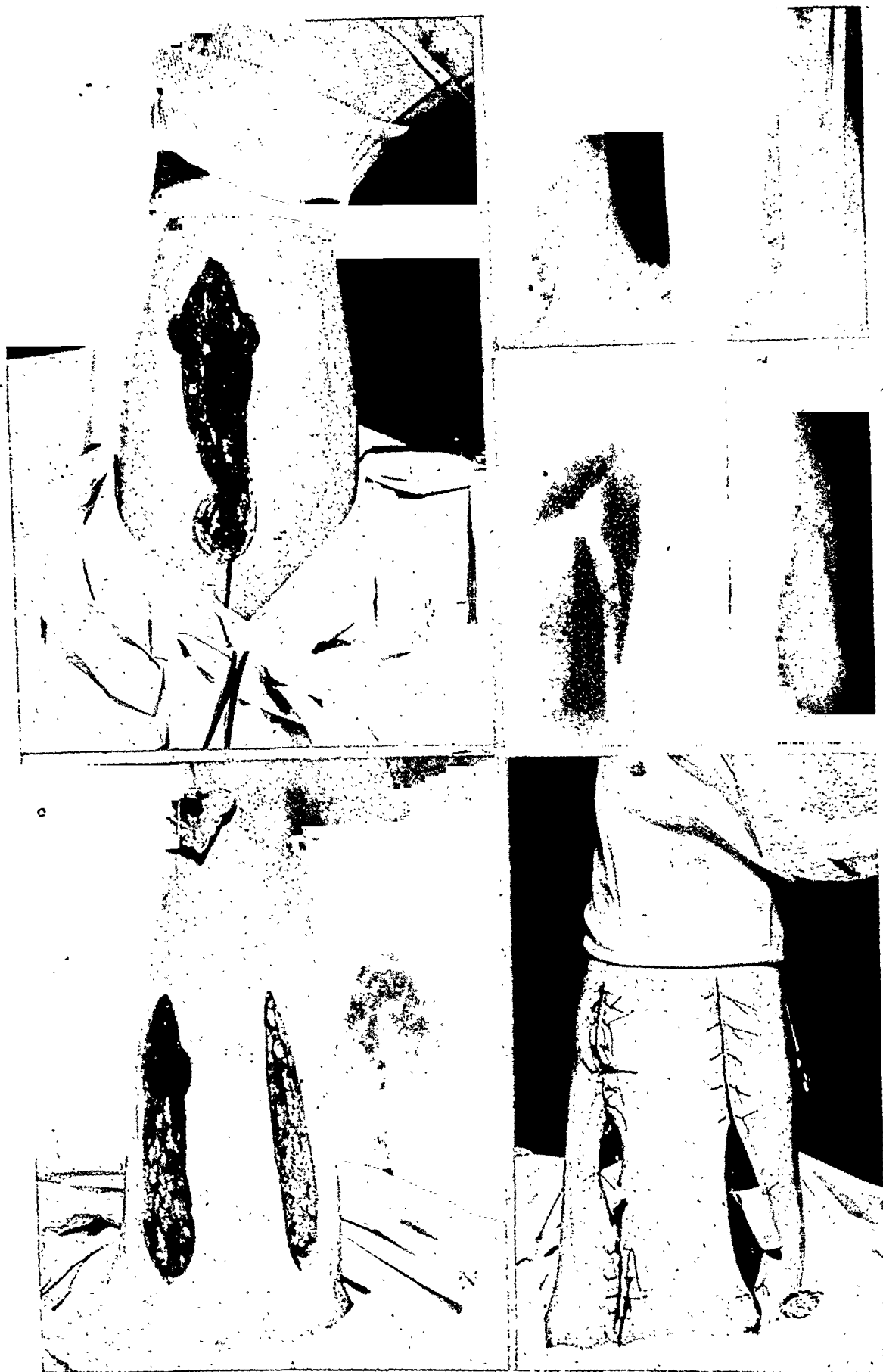


PLATE VI—Case 6: A. The old compounding wound in the operating room, 19 days after wounding.  
 B. The excised compounding wound and the posterolateral operative approach at the completion of the internal fixation.  
 C. Roentgenograms before and after fixation. The former are of films made soon after initial surgery and do not depict the shortening seen at operation.  
 D. The partial closure of each wound 26 October, 1944. The drains are separate and not through-and-through.

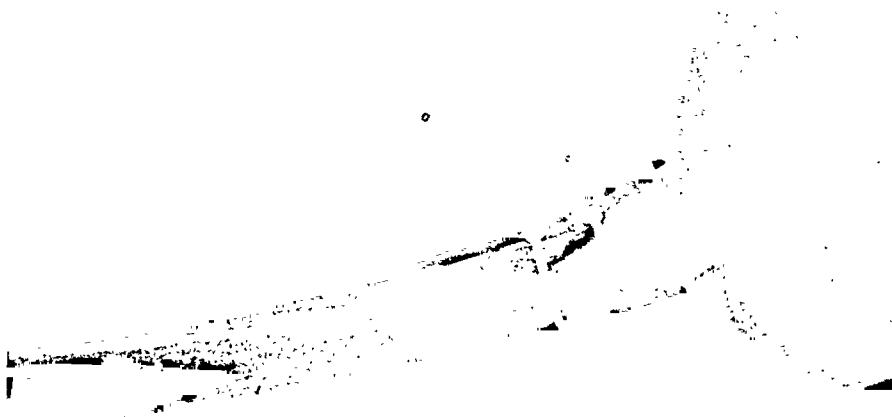
E



F



G



E. The almost healed wounds 15 November, 1944. Drainage recurred from the old compound (lateral) wound.

F. A. P. view of the united fracture in April, 1945. Note the absorption about the lower two screws.

G. Lateral view of the united fracture in April, 1945. Note the sequestrum.



PLATE VII.—Case 7: A. A. P. view made in Evacuation Hospital, 14 October, 1944. Note the separation at the joint line.  
 B. Lateral view made in Evacuation Hospital, 14 October, 1944. Note the rotation of the fractured condyle.  
 C. A. P. view, 21 March, 1945. The fracture is united with a congruous joint.  
 D. Lateral view, 21 March, 1945. The fracture is united, with a congruous joint.

#### Case 7\* (see Plate VII)

*Indication*—Obligate-3: A condylar fracture, with displacement.  
*Result*—"4" The fracture united and the wounds healed, without sequestration or removal of metal.

*Diagnosis*: Fracture, compound, mildly comminuted medial condyle of left femur.  
*Wounded*: October 14, 1944, missile—not recorded.

*Reparative Surgery*: On October 24, 1944, the joint congruity was restored by fixation of the displaced condyle with multiple screws

through a compounding wound. The compounding wounds were closed.

*Zone of Interior Record*: All wounds were healed on admission, and the fracture became solidly united. In March, 1945, knee joint motion was limited to about 15 degrees but plastic surgery upon the quadriceps tendon and the scars is anticipated.

\* This patient was managed by Lt. Col. George Duncan.

**Case 8** (This patient had fixations of the humerus and ulna)\*

*Humerus: Indication—Obligate-4:* Massive soft-tissue loss.

*Result—D:* The fracture united and the wounds healed but neither occurred until after removal of metal and sequestra. About six months were required for each, and the union is precarious.

*Radius and ulna: Indication—Obligate-2 and 4:* Reduction was not achieved by other measures (manipulation) and the displaced fragments projected through a large wound, which also demanded further procedures.

*Result—F:* The fracture did not unite and the wound did not heal until sequestra and metal were removed.

*Diagnosis:* 1. Fracture, compound, mildly comminuted right humerus midthird. 2. Fracture, compound, mildly comminuted right radius and ulna upper thirds. 3. Wound of buttocks and lower rectum with colostomy (not here considered).

*Wounded:* June 2, 1944, by high explosive shell fragments. While he was at the Evacuation Hospital, a diagnosis of gas gangrene was made and appropriate therapy was instituted.

*Reparative Surgery:* On June 12 he was admitted to the Base Hospital. Between June 16 and 18, three massive hemorrhages from the buttock wound required 6,500 cc. of blood and ligation of the hypogastric artery.

On June 22, the humerus was plated in reduction through the large compounding wound which was partially closed. An effort was made to reduce the radius and ulna and a "hanging-type cast" was applied. Adequate reduction of the forearm was not achieved. When his general condition was satisfactory, on July 22, the ulna was plated in reduction through a septic wound which was partially closed but all bone was not covered. Better drainage of the wound of the arm was established. After a somewhat stormy postoperative course, he was evacuated to the Zone of Interior in late August.

*Zone of Interior Record:* On admission, September 9, all wounds were draining and the plate on the ulna was visible. On October 7, sequestra and metal were removed from both the humerus and the ulna. Neither was united. At the next change of plaster, in early November, the humerus was stable but during an effort to correct the deformity of the forearm, the humerus was refractured. It reunited, the forearm did not unite, and all wounds healed. The colostomy had not been closed and a fecal sinus through the buttock remained in April, 1945. No illustrations for this case are available.

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\*No illustration accompanies this case.

# SHORTENING OF HUMERUS and REPAIR OF RADIAL NERVE

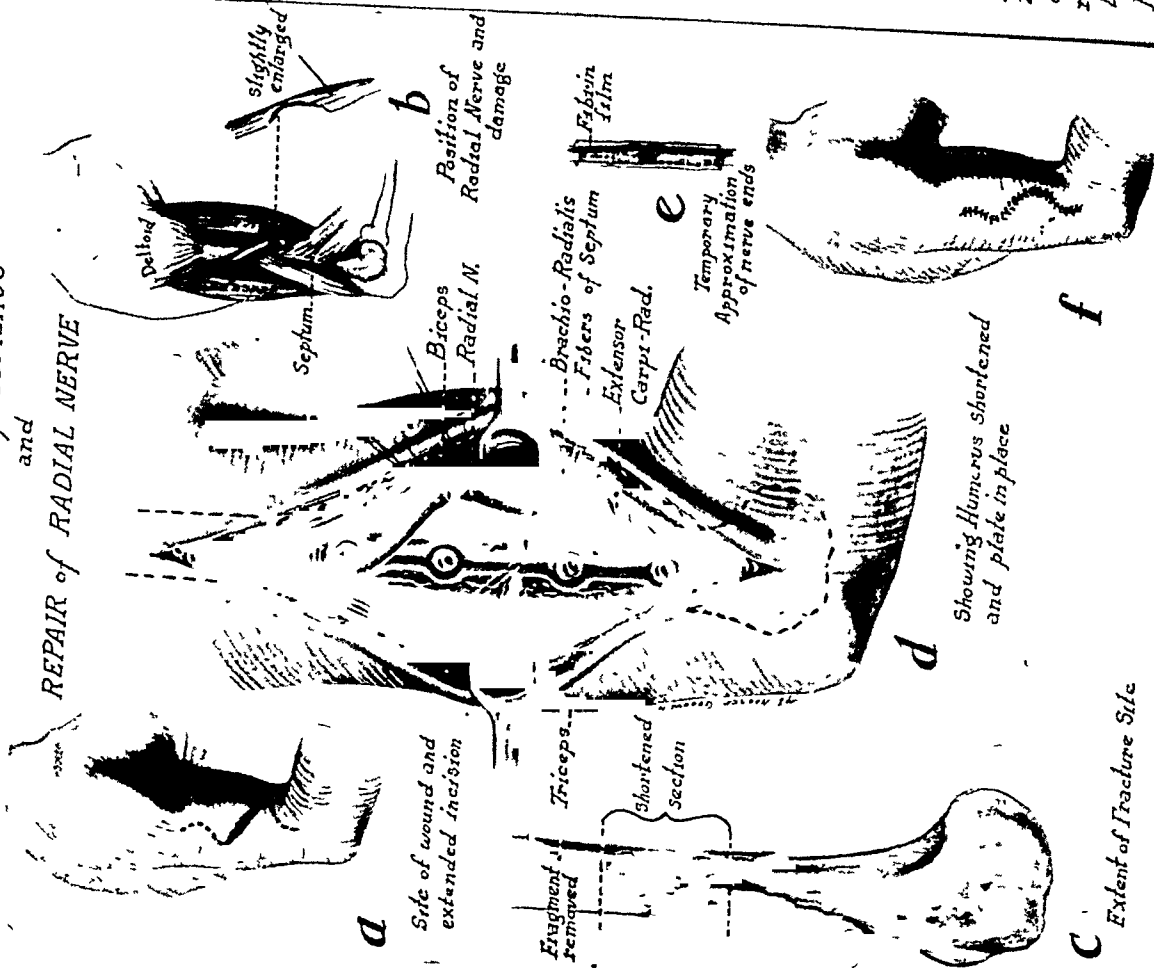
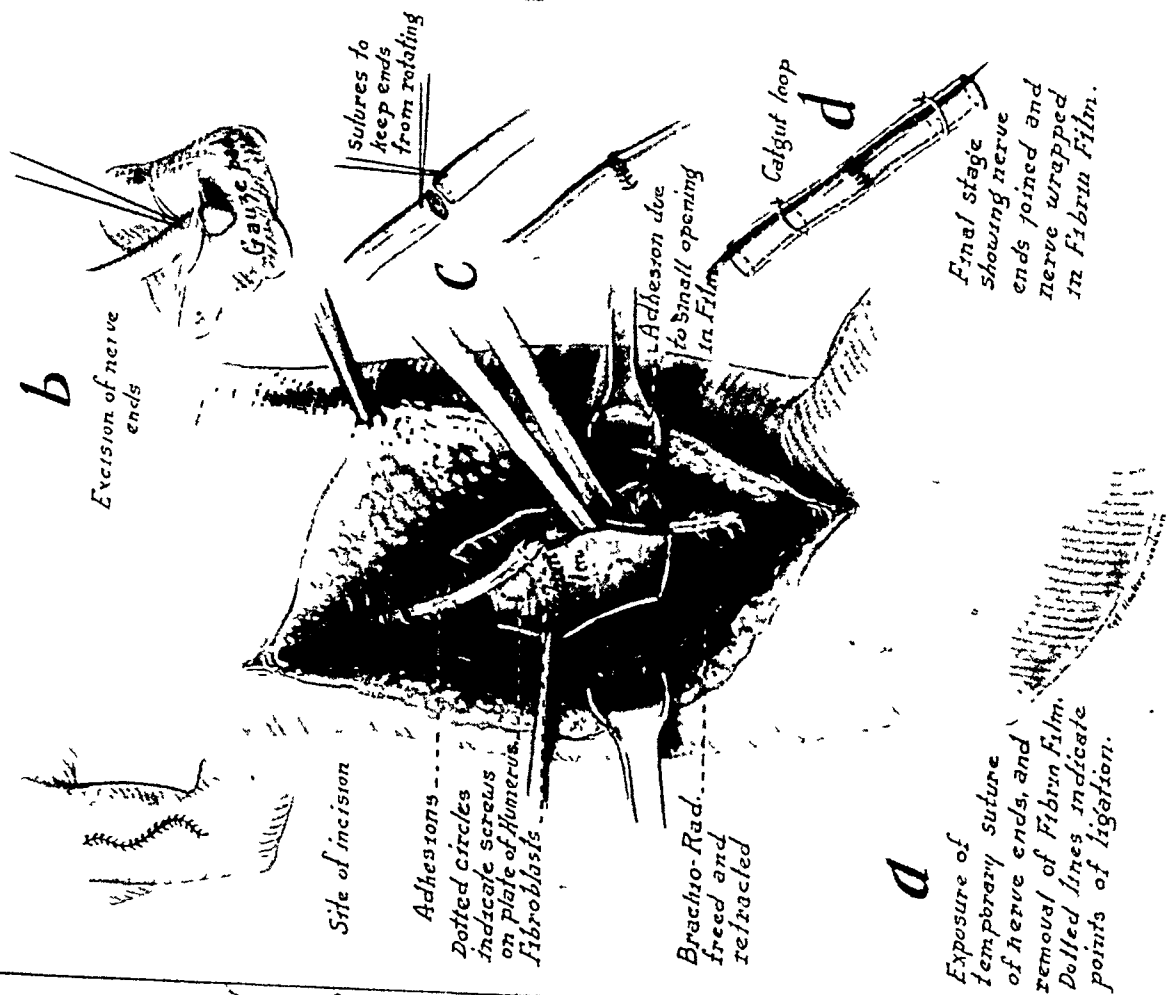


PLATE VIII.—Case 9: A. Artist's drawing of reparative procedure on 6 September.  
B. Artist's drawing of the definitive nerve repair.



## PLATE VIII—(Continued)

C



PLATE VIII (Continued)—C. The united fracture. The wound is healed.

## Case 9\* (see Plate VIII)

*Indication—Obligate-5:* Stabilization and, if necessary, bone shortening to facilitate peripheral nerve surgery.

*Result—A:* The fracture united, and the wounds healed, without sequestration or removal of metal.

*Diagnosis:* Fracture, compound, comminuted, right humerus with laceration and loss of substance of the radial nerve.

*Wounded:* August 26, 1944, missile—unknown.

*Reparative Surgery:* On September 6, at the routine wound visualization of reparative surgery, it was determined that there was loss of about one inch of substance of the radial nerve. The compounding wound was extended. The orthopedic surgeon resected about 1.5 inches of humerus and fixed the fracture in reduction by a four-hole plate plus one transfixion screw. The neurosurgeon approximated the nerve ends and wrapped them in fibrin film. The wound was closed. On September 22, when the wound was healed, a definitive suture of the radial nerve was performed through an operative incision, which healed promptly.

*Zone of Interior Record:* On admission, all wounds were healed. The fracture went on to solid union. At 5.5 months after repair of the nerve there were definite signs of partial recovery.

\* The neurosurgeon was Lt. Col. Henry G. Schwartz, the orthopedic surgeon was Major Joe M. Parker.

PLATE IX

A

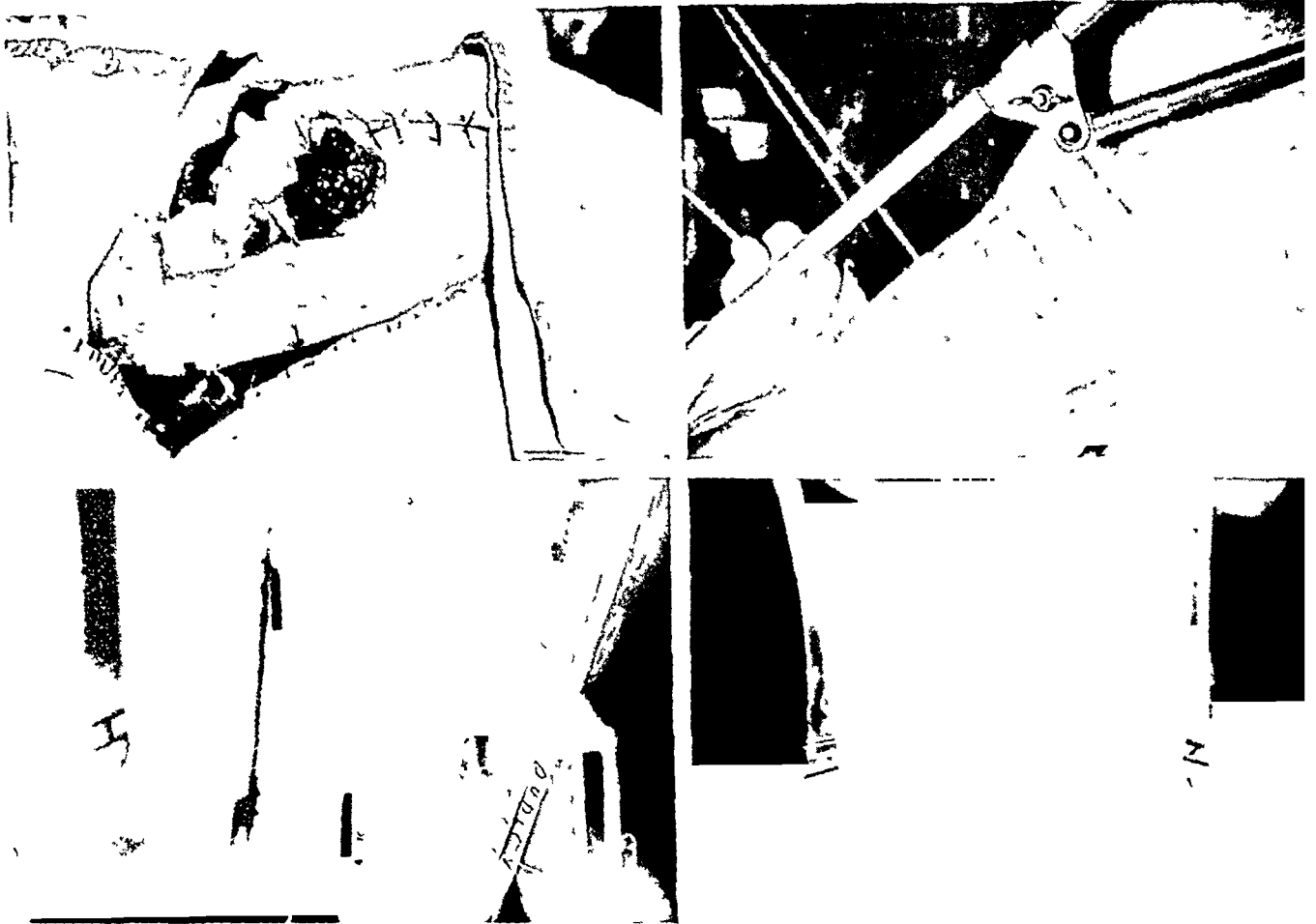


PLATE IX.—Case 10: A The fixation of the fracture through the compounding wound, with soft-tissue loss extended distally, 9 April, 1944.  
 B. The partial closure over denuded bone and the dependent drainage, 9 April, 1944.  
 C. The postoperative roentgenograms, 10 April.  
 D. The healing wounds in early July.  
 E. The united fracture in the Z. of I.

Case 10\* (see Plate IX)

*Indication*—Desirable in the femur—a fracture whose contour permits a rigid stabilization by multiple screws or a plate.

*Result*—A: The fracture united, and the wounds healed, without sequestration or removal of metal.



## PLATE IX—(Continued)



F

F The healed wounds and range of knee motion from extension in March, 1945

## Case 10 (Continued)

*Diagnosis:* Fracture, compound, complete, bilateral femur, junction mid and lower thirds. (Only the right is considered here.)

*Wounded:* March 26, 1944, by enemy machine gun bullets

*Reparative Surgery:* After adequate blood replacement therapy, on April 9, 1944, exposure of the right thigh revealed a soft-tissue defect of the thigh involving the vastus lateralis and rectus femoris. Through this wound and a distal extension, the femoral fracture was stabilized in reduction by four screws. The wound was partially closed, and dependent drainage was established. The patient was returned to bilateral skeletal traction. During convalescence, he participated in an excellent ward program for the return of knee motion. The soft-tissue defect filled with granulations, and all wounds were about healed when he was evacuated to the Zone of Interior in August.

*Zone of Interior Record:* On admission, all wounds were healed and the fractures united. When union in each fracture of the femur became sufficiently solid to permit it, weight-bearing in braces was begun. In March, 1945, he was ready for discharge from the army.

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\* This patient was managed by Captain John J. Modlin and Major Joe M. Parker.

# COMPOUND BATTLE FRACTURES

## PLATE X

A

B



C

PLATE X.—Case 11. A. A. P. and lateral views on admission to a Base Hospital.  
B. A. P. and lateral views after the fixation, 18 June, 1944 (One screw did not protrude through the opposite cortex.)  
C. Healed compounding wound and unhealed relaxation incision (which might have been split grafted at reparative surgery), 15 July, 1944

### Case 11\* (see Plate X)

*Indication*—Desirable for tibia and fibula—a fracture whose contour permits stable fixation by multiple screws, with minimal periosteal stripping.

*Result—A*: The fractures united in anatomic alignment, and the wounds healed, without sequestration or removal of metal.

*Diagnosis*: Fracture, compound, comminuted of left tibia and fibula, midthird.

*Wounded*: June 8, 1944, by high explosive shell fragments.

*Reparative Surgery*: On June 17, 1944, removal of the initial encasement revealed

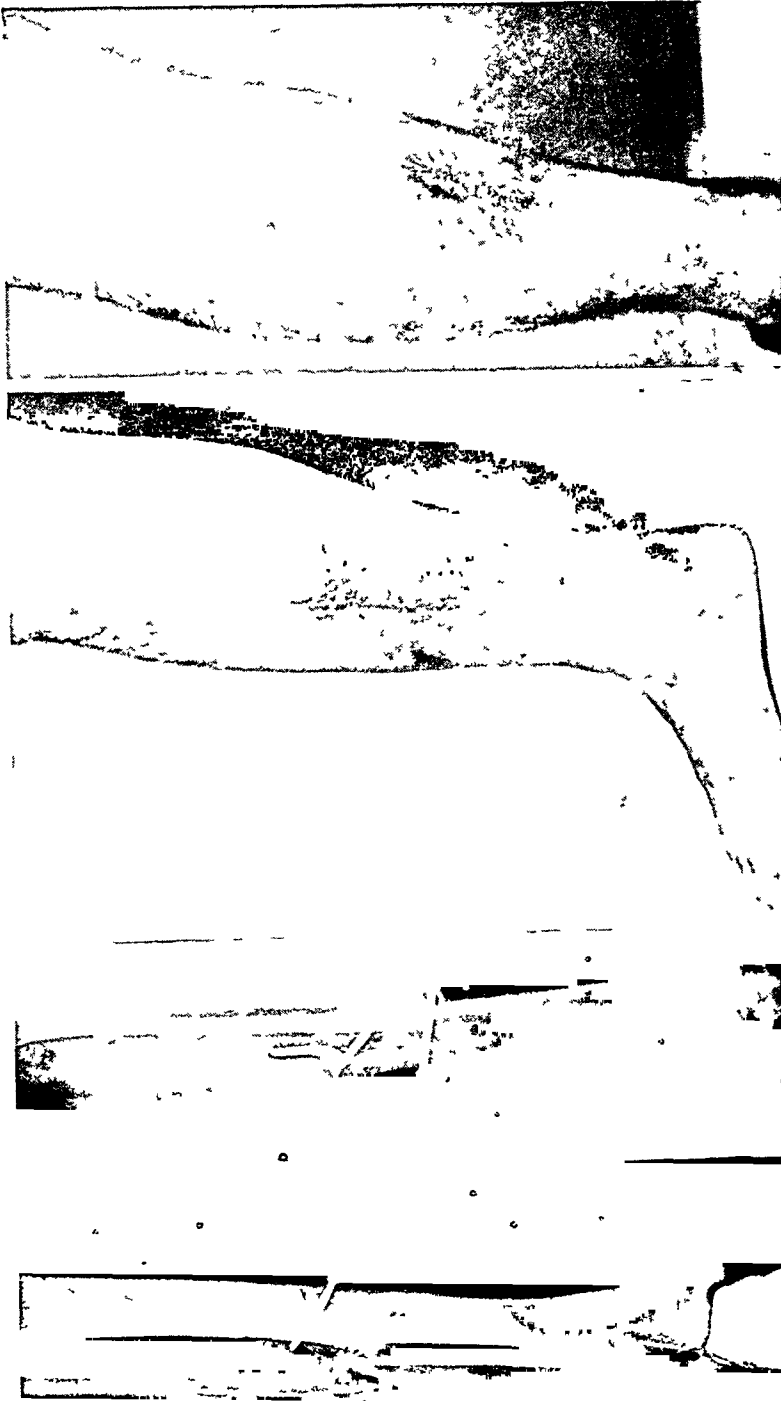


PLATE X.—(Continued) D The united fractures, 12 December, 1944 All wounds were healed several months before  
E The healed anteromedial wounds  
F The healed posterior wounds

### Case 11 (Continued)

two compounding wounds, one anteromedial, the other posterolateral. Through the former, the oblique fracture of the tibia was stabilized in anatomic reduction by three screws. A posteromedial relaxing incision permitted closure of the anteromedial wound. Drainage was established through the posterolateral compounding wound. The former compounding wounds healed before evacuation to the Zone of Interior.

*Zone of Interior Record*. On admission, on September 26, 1944, all wounds were healed and the fracture was united. After several months of rehabilitation, he was returned to duty. However, because of some tenderness over the site of a screw head, the screws were removed (one broke) on January 31, 1945.

\* This case was managed by Captain John J. Modlin

Case 12\*†

*Indication*—Desirable in the forearm—any fracture whose contour permits fixation in reduction by internal fixation.

*Result—A:* The fracture united and the wounds healed, without sequestration or removal of metal.

*Diagnosis:* 1. Fracture, compound, complete left radius (comminuted with some bone loss) and ulna (transverse), lower thirds. 2. Fracture, compound, comminuted left femur, midthird (not here considered).

*Wounded:* September 3, 1944, by enemy rifle fire.

*Reparative Surgery:* On September 11, through compounding wounds, the transverse fracture of the ulna was plated in reduction and a wire loop was used to hold fragments of radius in approximation. The wounds were closed with drainage.

The wounds of the thigh were closed with drainage and skeletal traction was instituted. All wounds healed.

*Zone of Interior Record:* On admission, October 24, the wounds were healed and the fractures stable. Bony union occurred with synostosis between the bones of the forearm. The metal was prophylactically removed in early April, 1945. No illustrations for this case are available.

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\* This patient was managed by Major Joe M. Parker and Captain Richard Crouch.

Case 13\*†

*Indication—Elective in the femur*—a nonobligate use of wire loops to hold approximation of fragments.

*Result—B:* The fracture united in excellent alignment and, after removal of sequestra and metal, the wound healed.

*Diagnosis:* Fracture, compound, comminuted right femur, midthird.

*Wounded:* July 1, 1944, missile—not recorded.

*Reparative Surgery:* July 7, 1944, through the compounding wound, a wire loop was placed so as to obtain contact of major fragments. The wound was closed with drainage. The extremity was returned to balance suspension skeletal traction for ten weeks.

*Zone of Interior Record:* On admission, October 10, a sinus led to the fracture site. The fracture was united in excellent alignment. On November 22, the wire and sequestra were removed, after which the wound healed promptly. Illustrations for this case are not available.

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\* This patient was managed by Major Joe M. Parker and Captain John J. Modlin.

† No illustrations accompany these cases.

**Case 14\*** (*see Plate XI*)

*Indication—Elective in the tibia-fibula*—an elected decision to stabilize a tibia in reduction by plating rather than first attempt reduction by other measures.

*Result—B:* The fracture united in excellent alignment and, after removal of metal and sequestra, the wound healed.

*Diagnosis:* 1. Fracture, compound, comminuted right tibia and fibula, lower third.  
2. Laceration posterior tibial artery and nerve.

*Wounded:* March 25, 1944, by high explosive shell fragments.

*Reparative Surgery:* On April 3, 1944, through an extended medial compounding wound, the tibia was plated in reduction. The plate was placed as far posterior as possible. The wound was closed except for an area of loss of skin, which was left open for drainage. A small compounding wound over the fibula was not closed. He was evacuated to the Zone of Interior in early May.

*Zone of Interior Record:* On admission, all wounds were healed, and the fracture united in normal time. In August, there was some drainage from the medial wound. The metal and several tiny sequestra were removed and the wound was closed, with *per primam* healing. He remains hospitalized because of the residual from the nerve injury.

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\* This case was managed by Major Newton Mead and Captain Richard Crouch.

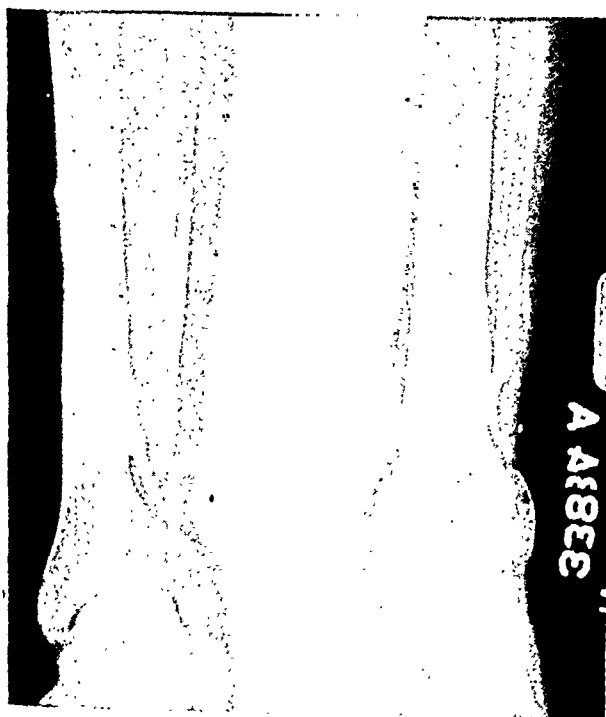


PLATE XI.—Case 14: A. The partially sutured wound following reparative surgery on 3 April, 1945.  
 B. The pre- and postoperative roentgenograms—(Note reversal)—Note the loss of bone at site of fracture in the fibula.  
 C. A. P. view and rotated A. P. view to show ankle mortise—showing the solid union, in good alignment, 30 March, 1945.  
 D. The range of ankle motion in April, 1945.

**Case 15\* (see Plate XII)**

*Indication—Elective in the tibia and fibula—Plating of the fibula.*

*Result—A:* The fracture united and the wounds healed, without sequestration or removal of metal.

*Diagnosis:* Fracture, compound, comminuted right tibia and fibula.

*Additional Diagnosis not here Considered:* Fracture, compound, comminuted of left humerus, with paralysis of the radial nerve.

*Wounded:* June 2, 1944, by high explosive shell fragments.

*Reparative Surgery:* On June 11, 1944, the fibula was plated through compounding wound which was closed with drainage. The compounding wound over the tibia was closed partially.

*Zone of Interior Record:* On admission, the wounds were healed. The fractures of the tibia and fibula united solidly. Because of some loss of tibial substance, full weight-bearing was delayed.

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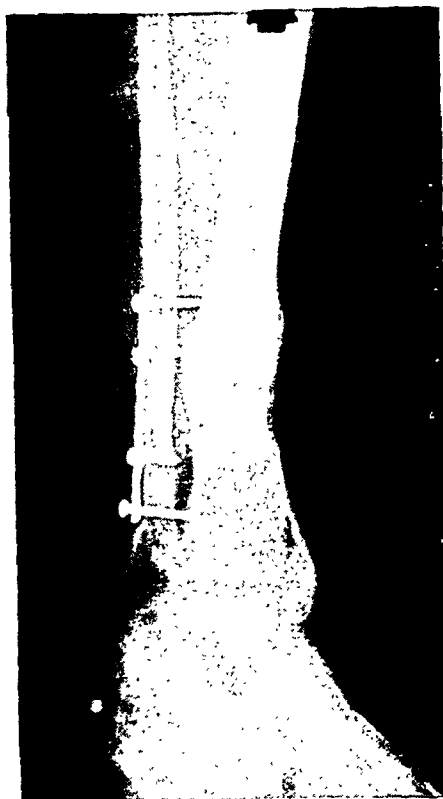
\* This patient was managed by Major Herbert W. Harris.

# COMPOUND BATTLE FRACTURES

## PLATE XII

A

B



C

D

E

PLATE XII.—Case 15: A. A. P. and lateral views on admission to Base Hospital, 9 June, 1944. Note the comminution in the tibia. Fractures in the lower third of the tibia are difficult to reduce.  
B. A. P. view on 8 April 1945. The fracture is united in excellent alignment.  
C. Lateral view on 8 April, 1945.  
D. Frontal view of leg, April, 1945. Note the severe soft-tissue loss.  
E. Side view of leg, April, 1945, showing the scar of the fixation wound.



**Case 16 (see Plate XIII)**

*Indication—Elective of tibia and fibula*—A nonobligate plating, without attempt at reduction by other measures.

*Result—B—S:* The fracture united but wound healing was not obtained until sequestra, which were massive, and metal were removed.

*Diagnosis:* 1. Fracture, compound, comminuted, right tibia and fibula. 2. Fracture, compound, comminuted of os calcis, and talus bilateral.

*Wounded:* July 10, 1944, by a land mine explosion.

*Reparative Surgery:* On July 16, 1944, the tibia was plated in reduction through the compounding wound, which was closed. Bilateral plaster encasements were applied. The wound over the tibia did not heal. When the plaster for evacuation to the Zone of Interior was applied on August 30, three inches of bare bone were visible.

*Zone of Interior Record:* All wounds were draining on admission, October 3, 1944. The metal was picked out on the ward on December 17. The fracture was stable, as there was a bridge of bone posteriorly. Later, sequestra were removed and then the wound healed. The bones of the foot are a distorted mass. Amputation might have been considered in all echelons.

A

B

C



D

E

F

PLATE XIII.—Case 16: A. A. P. view on admission to Base Hospital.  
 B. Lateral view on admission to Base Hospital.  
 C. A. P. view after internal fixation.  
 D. Lateral view after internal fixation.  
 E. A. P. view after removal of sequestra and metal. The fracture is united, but note the heavy sequestration reducing the strength of the bone.  
 F. Lateral view after removal of sequestra and metal. The fracture is united, but note the heavy sequestration reducing the strength of the bone.

**Case 17 (see Plate XIV)**

*Indication—Elective in the tibia and fibula*—Internal fixation by plating without a previous effort at reduction by other measures.

*Result—F:* The fracture did not unite, and the wounds did not heal. There was massive sequestration.

*Diagnosis:* Fracture, compound, comminuted left tibia and fibula, midthird.

*Wounded:* September 30, 1944, by high explosive shell fragments.

*Reparative Surgery:* On October 9, 1944, the fracture of the tibia was stabilized in reduction by a long plate and one transfixion screw through the wound, which was closed. Postoperative roentgenograms revealed a more distal fracture, which was not seen on the original films, with some displacement. A few days later this was fixed in reduction by two screws, and the wound again closed. Wound healing was not obtained.

*Zone of Interior Record:* On admission, January 18, 1945, the wound was gaping, revealing the metallic fixation and dead bone, which were removed. Since that time the wound has improved in appearance but in late March there was minimal drainage, and the fracture was not united.

PLATE XIV

B



A



D

C

PLATE XIV.—Case 17: A. A. P. and lateral views on admission to Base Hospital B. A. P. and lateral views after internal fixation. C. A. P. and lateral views on admission to Zone of Interior Hospital in January, 1945. D. A. P. and lateral views—t March, 1945—showing bone defect after removal of massive sequestra and metal.

## Case 18\*†

*Indication—Elective in the humerus*—A nonobligate internal fixation, without a previous effort at reduction with other measures.

*Result—A*: The fracture united in good alignment, without sequestration or removal of metal.

*Diagnosis*: Fracture, compound, comminuted, humerus.

*Wounded*: September 20, 1944, by a bullet.

*Reparative Surgery*: About October 1 three wire loops were placed to hold the fragments in contact through a compounding wound, which was closed. Wound healing followed.

*Zone of Interior Record*: On admission, December 20, the wounds were healed, and the fracture was united in good alignment. No illustrations for this case are available.

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\* This patient was managed by Major Irvin Cahen.

† This case not illustrated.

## Case 19 (see Plate XV)

*Diagnosis*: Fracture, compound, oblique left femur midthird.

*Wounded*: September 17, 1944, by high explosive shell fragments.

*Base Hospital Record*: On September 26 skeletal traction was instituted and the wound closed with drainage. The wounds healed, and fair apposition and good alignment of the fracture were obtained. After 16 weeks in traction, he was placed in a hip spica for evacuation to the Zone of Interior.

*Zone of Interior Record*: On admission, there was minimal lateral bowing. Traction was not reinstituted. Further bowing and angulation with a nonunion followed.

*Evaluation*: This fracture contour would have permitted stabilization in reduction by multiple screws. The results in the series here reported indicate that, by delayed internal fixation, a nonunion might have been obviated.

PLATE XV

A

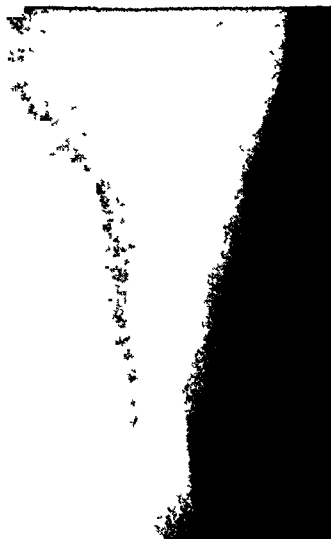
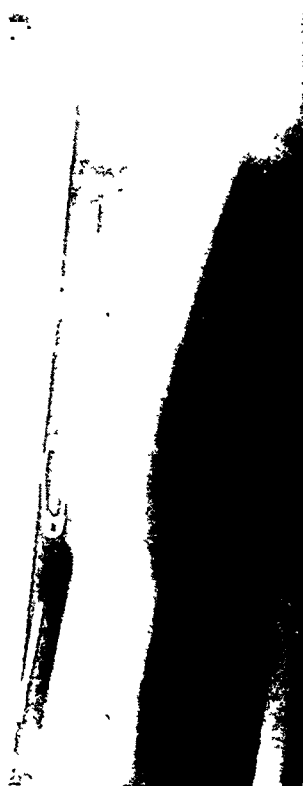
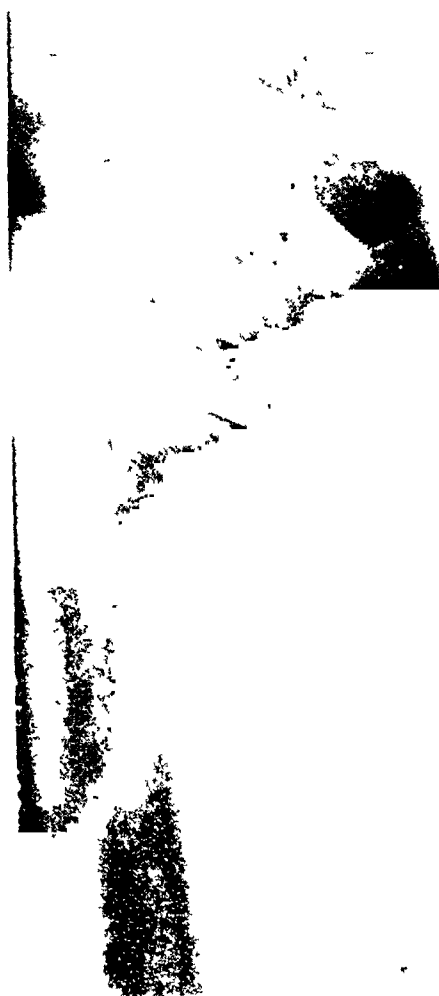


PLATE XV.—Case 19:  
A. A. P. and lateral  
while in traction over-  
seas



B. The nonunion in  
March, 1945.

B

**Case 20 (see Plate XVI)**

*Diagnosis:* Fracture, compound, comminuted, left humerus junction mid and lower thirds.

*Wounded:* January 21, 1944, by high explosive shell fragments.

*Base Hospital Record:* There was a definite segmental defect from bone loss. The fragments were pushed into approximation and a shoulder spica applied. The bony apposition was fair. The wounds healed, and the patient was evacuated to the Zone of Interior.

*Zone of Interior Record:* On admission, the wounds were healed, but a nonunion of the fracture was present. Several months later, bone grafting was performed. The extremity remains in plaster, but it is thought that union is occurring.

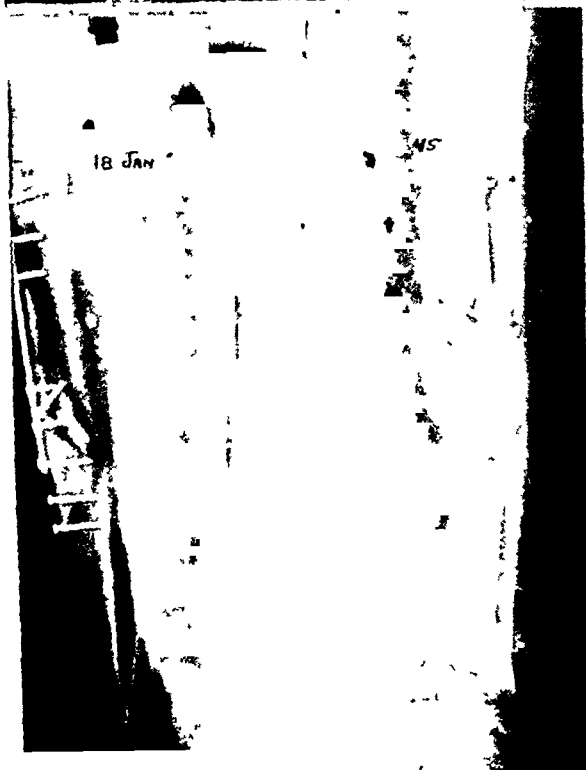
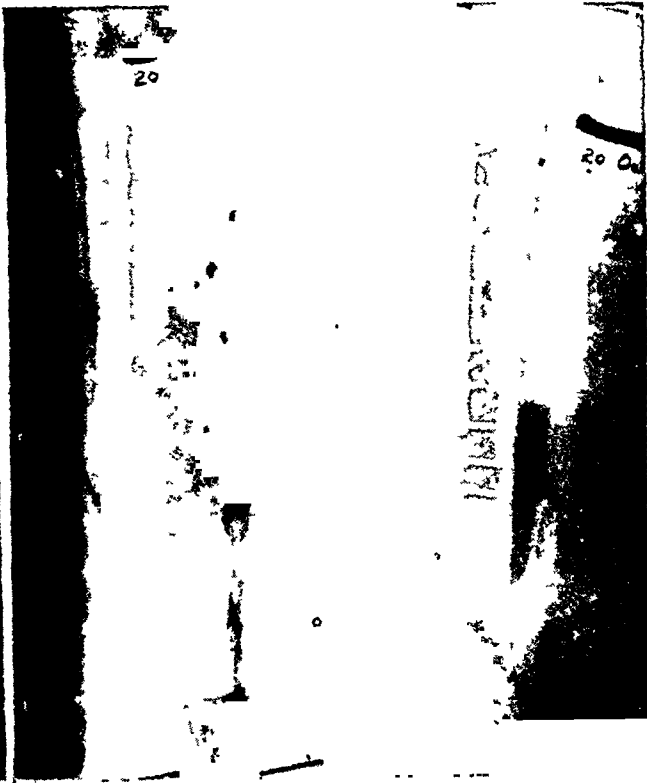
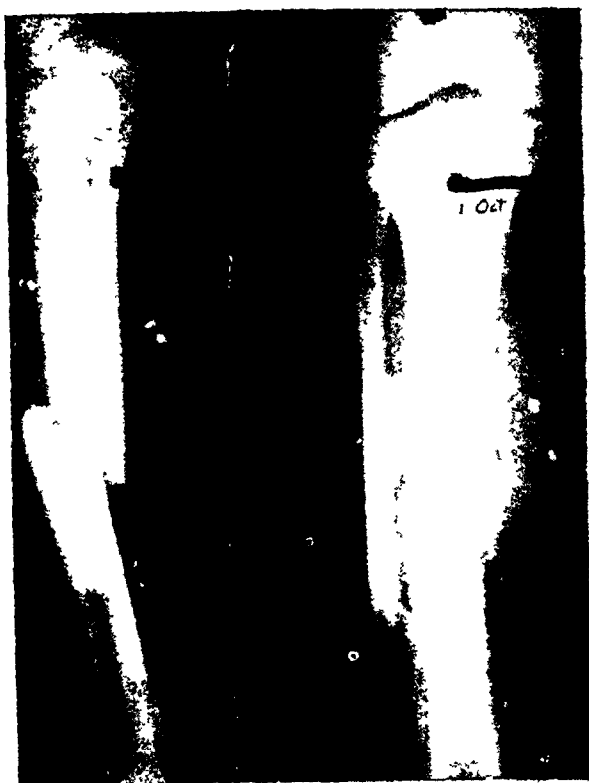
*Evaluation:* By the judicious use of delayed internal fixation (probably wire) improved bony contact could have been achieved, with enhanced chances of union of the fracture, as is evident in this series. Fifteen months after wounding this upper extremity is still immobilized, with bony union probable but not certain.

# COMPOUND BATTLE FRACTURES

## PLATE XVI

A

B



C

D

PLATE XVI—Case 20 A A P view of defect in humerus on admission to Base Hospital.  
B. Lateral view of defect in humerus on admission to Base Hospital.  
C. The reduction achieved by nonfixation measures A nonunion followed.



# THE SURGICAL SIGNIFICANCE OF THE ACCESSORY SPLEEN

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SPLENECTOMY, for certain diseases involving the formed elements within the blood, is gaining in breadth of application. A better understanding of the functional interrelation of the bone marrow, peripheral blood and spleen has resulted in a sounder basis for surgical therapy. In the development of the background of pathologic physiology of these diseases, as related to splenectomy, the accessory spleen has become recognized as playing a significant rôle in the end-result, particularly in congenital hemolytic icterus and primary thrombocytopenic purpura. If left to remain when once observed, or if overlooked at the time the spleen is removed, a recurrence of either may eventually become manifest. For several years this was assumed, since the histologic structure of the accessories was the same as that of the major spleen. Moreover, the pathologic activity observed supravitaly in the accessory was identical with that of the major spleen.<sup>1</sup>

Three types of observations have been made in establishing that the unremoved accessory spleen may eventually cause a recurrence of either congenital hemolytic icterus or primary thrombocytopenic purpura subsequent to splenectomy: First, recurrence associated with an accessory spleen *found but not removed* at the time of splenectomy since its significance was not then recognized; second, recurrences associated with accessory spleens overlooked at the time of splenectomy, but subsequently found at necropsy, after the patient had died of recurrence; and, third, the most convincing of all, relief from a recurrence by the surgical removal of accessory spleens at a second operation. Later, such instances will be described. Perhaps the same reasoning may be eventually applied in primary splenic neutropenia, pansplenic hematocytopenia, or even to some of the other less well-defined variations within the complex Banti's syndrome.

It is the purpose of this paper to present a list of the diseases for which 174 consecutive splenectomies, as well as four explorations for splenic disease, were accomplished (Table I); a tabulation of the location of 131 accessory spleens found in 56 of these patients (Table II); a survey of the pertinent literature and from these basic findings further to analyze the significance of the accessory spleen. Table I indicates that the two diseases for which the accessory spleen *should* be removed to prevent recurrence, namely, congenital hemolytic icterus and primary thrombocytopenic purpura, were also the two most frequent indications. The four exploratories were: one ligation of the splenic artery and three celiotomies during which the spleen was *thoroughly* examined but not removed. In addition, there was one *accessory splenectomy*

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for recurrent congenital hemolytic icterus (No. 21, Table I) (No. 7, Table II), subsequent to a previous splenectomy.

# THE INCIDENCE OF ACCESSORY SPLEENS

The incidence of accessory spleens has been variously reported by different observers. In the older necropsy reports it ranged around 10 per cent. Adami and Nichols<sup>2</sup> report an incidence of 11 per cent in their necropsies. Morrison,

TABLE I  
THE INDICATIONS FOR SPLENECTOMY OR EXPLORATORY CELIOTOMY

Disease	No. of Operations	Percentage of all Operations
1. Congenital hemolytic icterus.....	53	29.70%
2. Primary thrombocytopenic purpura (including 1 exploratory).....	33	18.50%
3. Banti's syndrome (including 2 exploratories and 1 ligature of the splenic artery).....	33	18.50%
4. Hypoplastic anemia.....	13	7.30%
5. Lymphatic leukemia.....	7	3.93%
6. Pansplenic hematocytopenia.....	6	3.37%
7. Hodgkin's disease.....	5	2.80%
8. Acquired hemolytic icterus.....	4	2.24%
9. Splenic neutropenia.....	4	2.24%
10. Myelogenous leukemia.....	4	2.24%
11. Traumatic rupture of spleen.....	3	1.68%
12. Polycythemia vera.....	2	1.12%
13. Splenic leukopenia.....	2	1.12%
14. Felty's syndrome.....	2	1.12%
15. Lymphosarcoma of the spleen.....	2	1.12%
16. Erythroblastic leukemia.....	1	0.56%
17. Moniliasis of the spleen.....	1	0.56%
18. Luetic splenomegaly.....	1	0.56%
19. Sickle cell anemia.....	1	0.56%
20. Portal cirrhosis with ascites.....	1	0.56%
Total splenectomies (174) and exploratories (4).....	178	
21. Recurrent congenital hemolytic icterus (2 accessories found and removed from one of the above cases) ..	1	

Lederer and Fradkin,<sup>3</sup> however, after thoroughly searching their necropsy material found an incidence of 35 per cent. They report that Sassuchin found 15 per cent in 153 necropsies of children under age ten. Jolly<sup>4</sup> observed 25 per cent in 80 children under age 17. Maingot<sup>5</sup> reported eight instances in a series of 18 splenectomies for essential thrombocytopenic purpura, an incidence of 44.4 per cent. Curtis and White<sup>6</sup> state that seven (20 per cent) of their first 35 splenectomies revealed accessory spleens. McLaughlin<sup>7</sup> reported a 24 per cent incidence in a series of 13 splenectomies for congenital hemolytic icterus.

The incidence of accessories found at necropsies with "normal" spleens should be differentiated from that of patients with splenic disease, since there may be an effect of the fundamental pathologic process upon the incidence of accessory splenic tissue. In our series, as listed in Table I, a total of 56 of our 178 consecutive patients presented accessory spleens. Fifty-three instances

were observed during the splenectomy, two at necropsy of previously splenectomized patients, and one at the time of a second operation, planned specifically to search for accessories in a patient with recurrence. This represents a general incidence of 31.4 per cent, as distributed throughout the various splenic disease and age-groups.

#### ACCESSORY SPLEENS IN THE VARIOUS AGE-GROUPS

Since the splenectomies were performed in relatively equal numbers in the first six decades (except for the third decade, Table III), the age-incidence of accessory spleens may be compared. Thus, Table III reveals that accessory spleens are more common in the earlier age-groups. This general tendency has also been noted in children without splenic disease. However, the 50 per cent incidence in the first decade, as well as the 39.1 per cent in the second, in this series with splenic disease, is considerably higher than reported incidences among "normal" children (15 per cent by Sassuchin and 25 per cent by Jolly). It agrees well with Maingot's<sup>5</sup> report of 44.4 per cent accessories in a series of 18 patients splenectomized for primary thrombocytopenic purpura.

Inasmuch as the incidence of accessory spleens is considered to decrease with advancing age, we may assume it occurs by some form of involutional atrophy. This ensues by processes similar to those which result in the decreased weight of the normal spleen in the aged and in a gradual percentage decrease of spleen weight from the time of birth onwards, both of which Krumbhaar<sup>8</sup> regarded as physiologic. Rocher<sup>9</sup> is said to have observed, at necropsy, many accessory spleens undergoing atrophy in infants. Thus, it may be suggested that an accessory spleen disappears during the normal process of involution unless it is influenced to remain by some intrinsic pathologic process, such as in primary thrombocytopenic purpura or congenital hemolytic icterus. The greater incidence of accessories in individuals with splenic disease over those with "normal" spleens may thus be clarified.

#### ACCESSORY SPLEENS IN CONGENITAL HEMOLYTIC ICTERUS AND PRIMARY THROMBOCYTOPENIC PURPURA

The greater incidence of accessory spleens in congenital hemolytic icterus (Table IV), compared to a similar age series in primary thrombocytopenic purpura (Table V), might be expected. Owing to its true genetic nature congenital hemolytic icterus may be active, even at the time of birth, when accessories are more numerous. Of the 53 splenectomies for congenital hemolytic icterus, 33 were in the first three decades (Table IV). Fifty-seven point one per cent of the patients in the first decade, and 42.8 per cent in the second presented accessory spleens (Table IV).

Of the 33 operations for primary thrombocytopenic purpura (all splenectomies save one exploratory) (Table V), 23 were during the first three decades. The incidence of accessory spleens, 44 per cent in the first decade and 33.3 per cent in the second, is less than in congenital hemolytic icterus. In but one instance were accessories found beyond the age of 29 in patients with thrombocytopenic purpura (Table II, No. 52).

# THE ACCESSORY SPLEEN

TABLE II

56 PATIENTS WITH 131 ACCESSORY SPLEENS FOUND DURING  
174 SPLENECTOMIES AND 4 EXPLORATORIES (TABLE I)

No.	Sex	Age	Date of Splenectomy	Disease	Description of Accessories from Operative Record
1.	F	10	4-26-34	Banti's syndrome	A small accessory at the hilus
2.	M	52	11-8-34	Hypoplastic anemia	One accessory, 1.5 cm. in diameter, retroperitoneal
3.	F	56	2-13-35	Cong. hemolytic icterus	One accessory, 1.5 cm. in diameter, posterior pedicle
4.	F	31	1-2-36	Cong. hemolytic icterus	Eight accessories, the largest 3 cm. in diameter, five about the hilus, three along the splenic vein in the pedicle, the smallest 2 or 3 mm. in diameter
5.	F	45	8-17-36	Banti's syndrome (ligature splenic artery)	Three accessories in the omentum
6.	M	41	5-8-37	Banti's syndrome	One small accessory, 8 mm. in diameter, in the pedicle
7.	F	9	2-22-38	Recurrent cong. hemolytic icterus	Two accessories, retroperitoneal above the tail of pancreas
8.	M	52	2-24-38	Hypoplastic anemia	Two accessories, 1 cm. and 2 cm. in diameter, in the anterior greater omentum
9.	F	68	11-28-39	Pansplenic hematocytopenia	One large accessory, 2 x 2 x 1.5 cm., at the hilus
10.	F	7	3-24-39	Cong. hemolytic icterus	Six accessories, largest 2 cm. in diameter, at the hilus
11.	M	24	4-7-39	Banti's syndrome	One accessory, 2 x 1 x 1.5 cm., at hilus
12.	F	39	6-3-40	Splenic neutropenia	Two accessories, one 1.5 x 1.5 x 1.5 cm., the other 1 x 1 x 1 cm., at pedicle
13.	M	12	6-8-39	Cong. hemolytic icterus	One accessory at lower part of pedicle
14.	F	40	11-4-40	Hodgkin's disease of spleen	One accessory, 1 cm. in diameter, on anterior great omentum just below transverse colon
15.	M	11	4-17-41	Cong. hemolytic icterus	Two small accessories, one at hilus, other within omentum
16.	F	46	4-24-41	Erythroblastic leukemia	One accessory, anterior surface of omentum
17.	M	12	5-13-41	Thrombocytopenic purpura	Three accessories, largest measuring 2 x 1 x 1 cm., all at hilus
18.	F	9 mos.	6-2-41	Cong. hemolytic icterus	Three accessories, largest 1 cm. in diameter, at hilus
19.	M	3	9-4-41	Cong. hemolytic icterus	One accessory, 1.5 cm. in diameter, retroperitoneal, near inferior pole of spleen
20.	M	48	9-9-41	Pansplenic hematocytopenia	One accessory, 2 cm. diameter, in bowel mesentery
21.	F	12	9-24-41	Thrombocytopenic purpura	Four accessories, all in the pedicle
22.	M	19	10-16-41	Banti's syndrome	Eight accessories, largest 1 cm. in diameter, all at pedicle
23.	M	7	12-1-41	Cong. hemolytic icterus	Four accessories, one in omentum, three at hilus, largest 3 x 2 x 2 cm.
24.	F	28	12-6-41	Cong. hemolytic icterus	One accessory, 2 x 2 x 1 cm., at hilus
25.	F	7.5 wks.	1-22-42	Cong. hemolytic icterus	One accessory at hilus
26.	M	8	2-13-42	Thrombocytopenic purpura	One accessory at hilus
27.	M	58	7-10-42	Banti's syndrome	One accessory, 1.5 cm., in omentum
28.	M	7	10-3-42	Banti's syndrome	Two accessories, in omentum on left side
29.	M	29	11-14-42	Banti's syndrome	One accessory at the hilus
30.	F	62	1-31-43	Cong. hemolytic icterus	One accessory at the hilus
31.	M	15	2-1-43	Banti's syndrome	Ten accessories, four at hilus, and six in the pedicle
32.	F	32	3-18-43	Hodgkin's disease of spleen	Two accessories, one at hilus, other in splenocolic ligament
33.	F	23	6-19-43	Banti's syndrome	Three accessories at hilus
34.	F	54	8-12-43	Polycythemia vera	Two accessories, one at hilus and one on omentum
35.	M	7	10-28-43	Banti's syndrome	Three accessories, in pedicle
36.	F	5	11-17-43	Thrombocytopenic purpura	One accessory at pedicle
37.	F	26	11-18-43	Thrombocytopenic purpura	One accessory at hilus
38.	M	59	11-20-43	Chronic lymphatic leukemia	Four accessories at hilus
39.	F	25	12-17-43	Lymphosarcoma	Five accessories, largest 2 cm. in diameter, at hilus

TABLE II—(Continued)

56 PATIENTS WITH 131 ACCESSORY SPLEENS FOUND DURING  
174 SPLENECTOMIES AND 4 EXPLORATORIES (TABLE I)

No.	Sex	Age	Date of Splenectomy	Disease	Description of Accessories from Operative Record
40.	M	10 mos.	1-2-44	Cong. hemolytic icterus	One accessory at pedicle
41.	F	27	1-12-44	Thrombocytopenic purpura	Two accessories at hilus
42.	F	9	2-24-44	Cong. hemolytic icterus	One accessory, 1.5 cm. in diameter, at hilus
43.	F	28	3-1-44	Cong. hemolytic icterus	One accessory, 3 x 2 x 2 cm., retroperitoneal to left of pedicle
44.	M	32	6-26-44	Hodgkin's disease of spleen	One accessory at hilus
45.	M	12	6-28-44	Cong. hemolytic icterus	Two small accessories, one at hilus, other on anterior omentum
46.	M	4	7-1-44	Thrombocytopenic purpura	One accessory at hilus
47.	M	5	7-8-44	Thrombocytopenic purpura	One accessory at hilus, 2 cm. in diameter
48.	M	22	7-15-44	Banti's syndrome	One accessory, 2 cm. in diameter, retroperitoneal, just lateral to and below the hilus
49.	F	58	7-21-44	Lymphatic leukemia	Five accessories, largest 2.5 cm. in diameter, at hilus
50.	F	22	7-24-44	Luetic splenomegaly	Three accessories, largest 1 cm. in diameter, at hilus
51.	F	71	10-9-44	Splenic neutropenia	Four accessories, largest 1 cm. in diameter, at hilus
52.	M	40	10-24-44	Thrombocytopenic purpura	Two accessories, one ant. and one post. to pedicle
53.	F	56	11-9-44	Cong. hemolytic icterus	Two accessories, one at hilus and one in splenocolic ligament
54.	M	47	2-26-45	Pansplenic hematocytopenia	Three small accessories at hilus

## ACCESSORY SPLEENS FOUND AT NECROPSY OF PREVIOUSLY SPLENECTOMIZED PATIENTS

No.	Sex	Age	Date of Death	Disease	Date of Splenectomy	Description of Accessories
55.	F	21	7-4-44	Thrombocytopenic purpura	9-9-42	Two small accessories, retroperitoneal, at tail of pancreas, 1.5 cm. diameter
56.	M	14	11-11-44	Banti's syndrome	3-9-44	Two accessories in great omentum just below left stomach, 8 mm. diameter

## INDIVIDUAL DISTRIBUTION

Only one accessory was found in each of 26 patients (Table II). The remainder, presenting more than one, are also listed in Table VI. Single accessories are more frequent in the younger age-group, likewise, multiple accessories. Thus, the patient with ten accessories is in the second, the patient with six in the first, and the two with eight are in the second and fourth decades, respectively (Table VI). The majority of multiple accessory spleens occur in the young. These findings strengthen the concept that accessory splenic tissue is more frequent during infancy and childhood.

## SPLENOSIS AND AUTOTRANSPLANTATION

There is another occurrence of multiple accessory spleens, however, which is apparently different. Thus, Albrecht,<sup>10</sup> in 1896, reported as many as 400 accessories in a single patient, and cited a similar case observed by Orth. Schilling<sup>11</sup> presented a patient whose peritoneum contained many small splenotic nodules. These were considered to be accessory spleens. At the present time these highly multiple splenules are not considered in the same category as the usual accessory spleen. Nevertheless, they constitute an

important variation, bearing a direct relationship to traumatic rupture of the spleen and to the technic of the usual splenectomy.

Moreover, von Kuttner,<sup>12</sup> in 1910, Faltin,<sup>13</sup> in 1911, von Stubenrauch,<sup>14</sup> in 1912, and again in 1920,<sup>15</sup> Lee,<sup>16</sup> in 1923, Kupperman,<sup>17</sup> in 1936, Shaw and Shafi,<sup>18</sup> in 1937, Jarcho and Anderson,<sup>19</sup> in 1939, and Hamrick and Bush,<sup>39</sup> in 1942, reported similar instances of patients with numerous small accessory spleens scattered throughout the peritoneal lining. These had all developed *subsequent to splenectomy for traumatic rupture of the spleen*. These small nodules in most instances contained the characteristic splenic pulp, however, the supporting framework, so characteristic of the spleen, was

TABLE III

AGE INCIDENCE OF SPLENECTOMIES AND EXPLORATORIES (TABLE I) WITH AGE INCIDENCE OF ACCESSORY SPLEENS (TABLE II)

Decade	No. of Cases Operated	No. of Cases with Accessories	Percentage Incidence of Accessories
1-9 yrs.	28	14	50.0%
10-19 yrs	23	9	39.1%
20-29 yrs.	43	11	25.5%
30-39 yrs	25	4	16.0%
40-49 yrs	22	7	31.8%
50-59 yrs.	25	8	32.0%
60-69 yrs.	11	2	18.1%
70-79 yrs.	1	1	100.0% (1 case)

TABLE IV

INCIDENCE OF ACCESSORY SPLEENS IN CONGENITAL HEMOLYTIC ICTERUS

Decade	No. of Cases Operated	No. of Cases with Accessories	Percentage Incidence of Accessories
1-9 yrs.	14	8	57.1%
10-19 yrs	7	3	42.8%
20-29 yrs	15	2	13.3%
30-39 yrs.	7	1	14.2%
40-49 yrs.	2	none	00.0%
50-59 yrs	7	2	28.4%
60-69 yrs	1	1	100.0% (1 case)

often more or less incomplete. In certain of the nodules the histologic structure was entirely normal. Buchbinder and Lipkoff,<sup>20</sup> in 1939, pointed out the similar sequence of events in all of these cases, namely: traumatic rupture of the spleen followed by splenectomy, then, after a variable lapse of time, subsequent inspection of the peritoneum either at operation or at necropsy reveals numerous small splenotic nodules, widespread, and in unusual locations.

Buchbinder and Lipkoff,<sup>20</sup> after reviewing the literature, report a similar case with a similar history. In their patient certain of the small accessories were located in the parietal peritoneum, as well as elsewhere along the peritoneal lining. The microscopic picture resembled normal splenic tissue, except for a paucity of lymph follicles and trabeculae as well as the presence of occasional atypically arranged blood vessels. These numerous small accessory spleens were considered as *transplants* resulting from seeding of the peritoneum subsequent to the scattering about of splenic fragments by hemorrhage from

the ruptured spleen. This concept was designated by Buchbinder and Lipkoff as "*splenosis*."

That splenosis resulted from the autotransplantation of splenic tissue was opposed by von Stubenrauch,<sup>14, 15</sup> who, reporting his case and subsequently another, was the most ardent proponent of the "splenoid" theory, which was at that time generally accepted. Von Stubenrauch reasoned that loss of splenic tissue can be compensated in several ways: by cellular changes in bone marrow and lymph nodes, as well as in preëxisting hemolymph nodes; by regeneration of the main mass of splenic tissue when incompletely removed or by hypertrophy of true accessory spleens; or by formation within the peritoneum of organs having a structure similar to that of splenic tissue which he named "splenoids." These splenoids formed as a sort of replace-

TABLE V  
INCIDENCE OF ACCESSORY SPLEENS IN PRIMARY THROMBOPENIC PURPURA

Decade	No. of Cases Operated	No. of Cases with Accessories	Percentage Incidence of Accessories
1-9 yrs.....	9	4	44.0%
10-19 yrs.....	6	2	33.3%
20-29 yrs.....	8	3	37.5%
30-39 yrs.....	3	0	00.0%
40-49 yrs.....	3	1	33.3%
50-59 yrs.....	2	0	00.0%
60-69 yrs.....	2	0	00.0%

TABLE VI  
NUMBER OF ACCESSORY SPLEENS PER PATIENT—BY DECADES

Decade	Patients with Acc.	One Acc.	Two Acc.	Three Acc.	Four Acc.	Five Acc.	Six Acc.	Eight Acc.	Ten Acc.
1-9 yrs.....	14	8	2	2	1		1		
10-19 yrs.....	9	2	3	1	1			1	1
20-29 yrs.....	11	6	2	2		1			
30-39 yrs.....	4	1	2					1	
40-49 yrs.....	7	4	1	2					
50-59 yrs.....	8	3	3		1	1			
60-69 yrs.....	2	2							
70-79 yrs.....	1				1				
Totals.....	56	26	13	7	4	2	1	2	1

Total of 131 accessories in 56 patients

ment for the removed spleen. Kreuter,<sup>21</sup> however, showed by his research on Rhesus monkeys that total splenectomy did not result in any such compensatory formations. Embryologically, the spleen develops from anlagen in a specific area of the celomic epithelium (left side of the dorsal mesogastrium). Von Stubenrauch carried his idea further by presuming that under exceptional circumstances epithelial anlagen might occur in a number of other foci, thereby giving rise to any number of splenic nodules.

The unusual anatomic locations in which splenotic nodules are found, as well as the circumstances under which they occur, argue convincingly against the "splenoid theory." Finding these nodules on the parietal peritoneum along the line of incision,<sup>18</sup> under the intestinal subserosa,<sup>12, 13, 16, 20</sup> on the peri-

toneum of the left diaphragm and on the liver surface,<sup>10, 18, 19, 39</sup> further discounts the theory since the splenic anlagen form on the *left* side of the cephalward portion of the dorsal mesogastrium, which is splanchnic mesoderm. Moreover, the location of nodules found in the lesser omentum and suspensory ligaments of the liver,<sup>11, 18, 19</sup> which were originally ventral mesogastrium, are further incompatible with the theory.

Splenosis has not been described following splenectomy for nontraumatic disease of the spleen, save in one questionable instance.<sup>7</sup> This raises further objection to the "splenoid theory." Thus, not removal of the spleen, but, rather trauma resulting in seeding of the peritoneum with small splenic fragments, appears to be the important factor in producing splenosis. The questionable case<sup>7</sup> may as reasonably be considered as splenosis resulting from peritoneal seeding with splenic fragments liberated during the process of a splenectomy. The findings reported are in accord with the mechanism of autotransplantation.

Splenosis subsequent to traumatic rupture of the spleen is but rarely encountered. However, its actual frequency is not known owing to the limited number of celiotomies, or of necropsies, on those abdomens in which splenectomy was previously successfully accomplished for traumatic rupture. Splenosis, according to our present knowledge, is best regarded clinically as an autotransplantation of splenic tissue.

Moreover, it is now well established that autotransplantation of splenic tissue may be readily accomplished experimentally. Even von Stubenrauch<sup>14</sup> successfully implanted autogenous splenic fragments in many and various experimental animals. He also observed that transplanted splenic tissue tends to regress, and consequently discounted the phenomenon of autogenous transplantation. Kreuter<sup>21</sup> excised the mammalian spleen and smeared its pulp over the peritoneal surfaces. Later, he found widely scattered nodules resembling splenic tissue. Putschar<sup>22</sup> went further in placing autogenous splenic implants in subcutaneous tissue, in addition to those on the peritoneum. All but two of Putschar's transplants developed into splenic nodules, even those developing within the subcutaneous tissue, remote from celomic epithelium.

Roettig, Nussbaum and Curtis<sup>23</sup> successfully implanted splenic tissue on the peritoneum (parietal as well as omental and mesenteric) in the rabbit. They observed that splenotic nodules became grossly visible in the rabbit not earlier than six months following the seeding of the peritoneal surfaces. Kupperman's report<sup>17</sup> of a 15-year-old boy developing splenosis within six months after an emergency splenectomy for traumatic rupture, indicates that, in man occurs an even more rapid development of splenic tissue transplanted to peritoneum. Putschar,<sup>22</sup> and also Perla,<sup>24</sup> observed serially in rats that splenic transplants to muscle and subcutaneous tissue fully regenerate within a period of from two to three weeks.

Shaw and Shafi,<sup>18</sup> after studying their patient with splenosis, report an atypical framework within the splenotic nodules. They even found one nodule in the left pleural cavity at the level of the eighth dorsal vertebra and another



just inside the capsule of the left lobe of the liver. It was difficult to explain their presence in these locations save by assuming an unrecognized rent in the diaphragm or a tear in the liver surface, which healed without leaving a visible scar. We have found no instance reported wherein these splenotic nodules, arising after splenectomy for rupture of a normal spleen, subsequently became the seat of primary splenic disease.

#### SPLENOSIS FOLLOWING THE USUAL SPLENECTOMY

The mechanism active in the establishment of splenosis thus becomes of clinical significance during a splenectomy for primary splenic disease, since the spleen may be accidentally torn either during manipulation of dislocation or because of capsular adhesions. Resultant fragments may thus fall onto peritoneal surfaces where they implant and thus give rise to splenosis. In a patient with congenital hemolytic icterus it is reasonable to assume that such might result in a recurrence. As reported by McLaughlin,<sup>7</sup> a patient with congenital hemolytic icterus remained well for two years following splenectomy, and then suffered recurrence. During the succeeding five years she was given 90 blood transfusions. At necropsy, a striking enlargement of all abdominal "hemolymph" nodes, ranging from 1 to 3 cm. in diameter, was observed. No accessory splenic tissue was reported even after careful search.

The now well-established concept of splenosis, with autotransplants spread throughout the peritoneal surfaces, the similarity in structure of the hemolymph nodes as well as their infrequency of occurrence and limited distribution, all give rise to some uncertainty. Perhaps it is more reasonable to regard this case as an example of accidental "seeding" of the peritoneal surfaces with splenic tissue during a difficult splenectomy, rather than as a compensatory enlargement of differing lymph nodes. Following such a concept, we should even be cautioned as to the technic of splenectomy, to avoid tearing of the spleen or after such an injury, against the spilling of splenic tissue out into the peritoneal cavity. Taking note of the successful transplantations of Putschar,<sup>22</sup> and Perla,<sup>24</sup> into subcutaneous tissue and muscle, we should avoid "contamination" even of the abdominal wound.

#### SURGICAL LOCATION OF ACCESSORY SPLEENS

To avoid overlooking accessory spleens a routine search should be made, after the major spleen has been removed and hemostasis effected, in the following approximate order: (1) The hilar region; (2) the splenic pedicle; (3) the retroperitoneal region surrounding the tail of the pancreas; (4) the great omentum, and especially along its attachment to the greater curvature of the stomach; (5) the splenocolic ligamentary attachments; (6) the mesentery of both large and small intestines; and (7) in the female, the left adnexa. Because in three out of four<sup>34</sup> (36—Table II, No. 7) (Table II, No. 55) proved recurrences, the overlooked accessory spleens were later found in the retroperitoneal region, about the tail of the pancreas, this area should be searched with especial care. Moreover, owing to our present knowledge of splenosis, search should also be made for any fragments torn off because of

capsular adhesions or clamping too close to the hilus when a short pedicle is encountered. The location incidence of 131 accessories found in the 56 patients is presented in Table VII. This reveals an increasingly greater incidence, a doubling frequency, as one approaches the hilus of the major spleen.

Accessory spleens have also been reported in other regions, as in the tail and body of the pancreas, and even in the scrotum attached to the tunica albuginea of the left testis.<sup>25, 26, 27</sup> According to the diminishing frequency of

TABLE VII  
LOCATION OF 131 ACCESSORY SPLEENS

Location	No. of Accessories	Percentage Incidence
Hilus.....	71 accessories	54.20%
Pedicle.....	33 accessories	25.10%
Omentum.....	16 accessories	12.20%
Retroperitoneal.....	8 accessories	6.10%
Splenocolic ligament.....	2 accessories	1.50%
Bowel mesentery.....	1 accessory	0.75%

accessories as one departs from the major spleen (Table VII), an indicated 3 per cent may possibly be found in the region of the pancreas, a further indication for careful exploration of this region after the splenectomy.

THE DISTRIBUTION OF ACCESSORY SPLEENS ✓

Accessory spleens but rarely occur in two different locations in the same individual (eight times in 178 cases) (Tables II and VIII). Eighty-five point seven per cent of the patients with accessories, varying from one to eight in number, had them in a *single location*. *In no instance were accessory spleens found in more than two locations in the same patient (Table VIII)*. In all eight instances of double location, accessories at the hilus always constituted one (hilus and omentum, four cases; hilus and pedicle, two cases; hilus and splenocolic ligament, two cases—total eight). The location of accessory spleens may be described as *hilar*, *at the pedicle*, or *in the omentum*, rather than in designated splenic ligaments. This appears the more fundamental since it indicates their distance from the major spleen, a significant factor in their development.

In two instances of unusual locations of accessory spleens the pattern of distribution did not vary from that observed in this series. In a patient with Hodgkin's disease with complete *situs inversus*, Rhodes and Grunberg<sup>28</sup> found at necropsy nine accessory spleens separately suspended from the greater curvature of the stomach, a single location. Also Olken's case<sup>27</sup> presented, in addition to a left scrotal accessory, a second accessory spleen at the hilus.

THE EMBRYOLOGIC BACKGROUND

The occurrence of accessory spleens as well as their various locations, even in the scrotum, can be more clearly understood by considering five phases of splenic embryonic development<sup>29, 30</sup>: (1) the manner of formation of the

major spleen, with its notches and lobulations, by fusion of separate splenic masses originating on the left side of the dorsal mesogastrium; (2) the formation of accessory spleens by failure of splenic anlagen to fuse; (3) the formation and development of the subjacent dorsal mesogastrium into the various peritoneal ligaments and bursae, carrying along the accessory spleens to their various distant locations; (4) the development of the splenic artery and its branches, providing a similar blood supply to both splenic lobules and accessory spleens<sup>32</sup>; and (5) the embryonic contiguity of the splenic anlagen to the genital ridge, permitting an accessory spleen to become attached to the left gonad.<sup>25, 26, 27</sup>

The splanchnic mesoderm surrounds the entodermal gut tube, forming a dorsal mesogastrium which suspends the embryonic gut from the midesophagus to the cloaca. Dorsal to the stomach the mesothelium and subjacent cells on the *left* side of the dorsal mesogastrium differentiate to form several splenic anlagen. Microscopically, the splenic anlagen appear as areas of varying size and differentiation. By subsequent fusion of many of these splenic aggregates, a single organ is eventually formed. One or more of these small splenic "hillocks" may not form close enough to the main group, or early enough to fuse with them, and, thus, an accessory spleen may be formed. The notches and lobules of the major spleen appear to originate as a result of partial or incomplete fusion of separate splenic masses.<sup>32</sup>

Whether failure or fusion occurs cephalad, ventrad, or caudad from the major masses, and whether this occurs early or later in embryonic development, appears to determine the eventual location of the accessory spleen. If failure of fusion occurs immediately ventrad, relatively late in development, hilar accessories presumably will occur. If the same splenic mass fails to fuse earlier, the subjacent growing dorsal mesogastrium will displace it from the hilus, presumably to become a pedicle accessory spleen. The same phenomenon underlies omental accessories when one takes into consideration that the great omentum began as part of the mesogastrium immediately dorsal to the greater curvature of the stomach.

Accessories within the intestinal mesentery result from an early failure of fusion of an anlage caudad to the aggregate splenic mass. An accessory in the splenocolic ligament arises from a splenic anlage in that part of the primitive mesentery of the colon that does not fuse with the parietal peritoneum but which becomes fused to the peritoneum of the splenic pedicle. No accessories have been found in the head of the pancreas, which originates as a *ventral* budding of the gut entoderm. However, accessories do occur about the body and tail, which is surrounded by the dorsal mesogastrium from which the splenic anlagen arise.

Retroperitoneal accessories become thus situated because they are within those portions of dorsal mesentery which fuse to the posterior parietal peritoneum, such as the mesentery of the colon and the mesentery dorsal to the pancreas. Paul<sup>31</sup> reports the instance of two retroperitoneal accessory spleens just lateral to the peritoneal attachments of the ascending colon on the right

TABLE VIII  
NUMBER OF ACCESSORY SPLEENS IN EACH LOCATION PER PATIENT

Case No.	Acc. at Hilus	Acc. at Pedicle	Acc. in Omentum	Accessories Retroperitoneal	Acc. in Spleno-colic Lig.	Acc. in Bowel Mesentery
1.....	1					
2.....				1		
3.....		1				
4*.....	5	3				
5.....			3			
6.....		1				
7.....				2		
8.....			2			
9.....	1					
10.....	6					
11.....	1					
12.....		2				
13.....		1				
14.....			1			
15*.....	1		1			
16.....			1			
17.....	3					
18.....	3					
19.....				1		
20.....						1
21.....		4				
22.....		8				
23*.....	3		1			
24.....	1					
25.....	1					
26.....	1					
27.....			1			
28.....			2			
29.....	1					
30.....	1					
31*.....	4	6				
32*.....	1				1	
33.....	3					
34*.....	1		1			
35.....		3				
36.....		1				
37.....	1					
38.....	4					
39.....	5					
40.....		1				
41.....	2					
42.....	1					
43.....				1		
44.....	1					
45*.....	1		1			
46.....	1					
47.....	1					
48.....				1		
49.....	5					
50.....	3					
51.....	4					
52.....		2				
53*.....	1				1	
54.....	3					
55.....				2		
56.....			2			

\* Patients presenting accessory spleens in two different locations.

side. This right-sided location is presumably the result of rotation and elongation of the developing colon together with its suspending mesentery. Mediastinal accessory spleens presumably may occur<sup>18</sup> as a result of embryonic factors, since the dorsal mesogastrium originally extends into the mediastinum, suspending the esophagus. They result by failure of fusion of a cephalad splenic mass.

An accessory spleen attached to the tunica albuginea of the left testis or to the mesovarium of the left ovary may be traced to the original close proximity of the mesonephros with its medially placed genital ridge, to the embryonic spleen. A splenic mass, contiguous to the genital ridge, may attach itself to the gonadal anlage and later actually descend into the left scrotum or pelvis.

Variations in the anatomic pattern of the splenic artery, and of the associated morphology,<sup>32</sup> also indicate that the spleen develops from multiple anlagen. Ssosan-Jaroschewitsch described two types of splenic artery: (1) The "magistral" type, which is a long single artery dividing near the hilus into two or three terminal branches; and (2) the "distributed" type, in which a short artery divides into eight to 12 branches relatively far from the spleen. Furthermore, the "distributed" splenic artery was usually associated with a greatly lobulated and unevenly contoured spleen, whereas the "magistral" was usually associated with a spleen of relatively smooth contour. Michels<sup>32</sup> pointed out that the tubercles and lobules of the spleen were supplied by separate arterial twigs which arose from splenic artery branches, and that areas separated by incisurae also had separate arterial supplies. A developmental history of multiple splenic anlagen, each with its own arterial twig, accounts for such a separate blood supply.

Michels incidentally describes a few instances of accessory spleens, found in the gastrosplenic and splenocolic ligaments, which received their blood supply from the inferior polar branches of the splenic artery. The accessory spleen, supplied by a branch of one of the splenic artery terminals, which also supplies a major spleen lobule, furnished further evidence that its origin was as one of the aggregate masses intended to form part of the spleen early in development, but having failed to fuse, carried with it its original blood supply. Thus, the accessory spleen represents a greater degree of fusion-failure when compared to cleft and lobule formation of the major spleen.

The origin of an accessory spleen, found attached to the tunica albuginea of the left testis is vividly indicated in Olken's case.<sup>27</sup> A continuous narrow bridge of splenic tissue extended from the scrotal accessory up through the inguinal canal and internal inguinal ring to connect with the posterior inferior aspect of the major spleen, which occupied its normal position. Sneath's case<sup>25</sup> is similar, except for a gap in the splenic bridge in the lower abdomen. The splenic tissue tapers to a thin cord below the spleen, and continues as a thin strand of peritoneum to the scrotal accessory. The case reported by Emmett and Dreyfuss<sup>26</sup> did not present the connecting link of splenic tissue, but in its place was a fibrous band.

In the embryo the contiguity of the left genital ridge, lying along the medial side of the mesonephros, to the developing spleen permits a splenic anlage to become attached to the mesentery of the embryonic gonad. The developmental descent of the gonad with its mesentery thereupon carries the attached spleen into the left pelvis in the female or into the left scrotal sac. Judging from Sneath's and Olken's cases, separation of the gonadal accessory spleen from the major spleen may be incomplete, and from Emmett and Dreyfuss' case, complete.

#### ACCESSORY SPLEENS CAUSE RECURRENCE

Morrison, Lederer and Fradkin<sup>3</sup> originally called attention to accessory splenic tissue as a probable cause of recurrence following splenectomy for primary thrombocytopenic purpura. They reported two cases for which splenectomy was successfully accomplished, yet only one fully recovered. At the time of splenectomy in the case that did not recover, an accessory spleen was observed but not removed, because its significance was then not fully appreciated.

Curtis and White<sup>6</sup> regarded the unremoved accessory spleen as the cause of recurrence following splenectomy for congenital hemolytic icterus or for primary thrombocytopenic purpura. They refer to hemolymph nodes as possibly capable of either continuing or acquiring hemolytic properties in excess of normal and thereby contributing to the recurrence of congenital hemolytic icterus. Vaughn,<sup>33</sup> in a review of the treatment of primary thrombocytopenic purpura, stated that relapse occurring subsequent to a period of satisfactory recovery after the splenectomy was probably due to the development of a spleniculus. Moreover, he tabulated a 17 per cent recurrence of primary thrombocytopenic purpura following splenectomy in 303 cases collected from the literature. Watson and Moir<sup>34</sup> suggest that the 11 per cent incidence of accessory spleens found by pathologists (Adami and Nichols<sup>2</sup>), compares closely enough with the 17 per cent incidence of recurrence to explain its cause.

Watson and Moir<sup>34</sup> reported primary thrombocytopenic purpura in a woman of 43 for whom splenectomy was accomplished and following which she was practically well for six years, although occasionally mild symptoms were noted. Recurrence of the severe hemorrhagic tendency finally caused the patient's death. At necropsy, an accessory spleen was found one centimeter above the tail of the pancreas, and measured 2.8 cm. in diameter. This weighed 12 Gm., and was verified microscopically. Sufficient megakaryocytes were noted in the bone marrow. The idea that accessory spleens might be the cause of the recurrence was advanced even before the patient's death but was not seriously considered.

McLaughlin, Sharpe, and Cunningham,<sup>35</sup> in discussing the results of splenectomy for familial hemolytic jaundice, reported 13 cases. They advanced the opinion that when sufficient evidence of hemolysis reappears, subsequent to splenectomy, it may be assumed either that (1) the original

diagnosis was incorrect; or (2) that overlooked splenic tissue had become active; or (3) that hemolymph nodes had hypertrophied and assumed excessive hemolytic activity. McLaughlin<sup>7</sup> cites an instance, previously referred to under splenosis, of congenital hemolytic icterus remaining well for a period of about two years subsequent to splenectomy. At the end of this interval the patient developed profound anemia because of recurrence. At necropsy a striking enlargement of the "abdominal hemolymph nodes," ranging from 1 to 3 cm. in diameter, was observed. No accessory splenic tissue was found by the pathologist, in spite of a careful search. This latter report is not entirely clear to us. Hemolymph tissue is not frequent in the human abdomen. Moreover, its distribution is limited. There might even arise some question as to its identity and histologic differentiation. The evidence, both clinical and experimental of autotransplantation as the cause of splenosis, as well as the fact that hemolymph tissue may resemble the atypical splenotic structures, would favor this case as one of recurrence due to the development of splenosis from "seeding" of the peritoneum at the time of splenectomy.

#### OUR OWN TWO RECURRENCES

Two pertinent cases indicating that accessory spleens, if left behind at the time of splenectomy, can cause recurrence of the primary splenic disease (congenital hemolytic icterus or primary thrombocytopenic purpura) for which the spleen was originally removed, occurred in this series of 174 consecutive splenectomies.

The first, referred to by Dr. Charles A. Doan,<sup>36</sup> in 1940, is as follows:

#### CASE REPORTS

**Case 1.**—G. P., female, age 4.5 years, entered the University Hospital, September 12, 1933, appearing pale and listless. She had always been somewhat anemic. Three months previously she began experiencing sudden episodes of listlessness. One month previously she suffered a similar attack with which was associated definite icterus. Her family history later revealed the familial tendency to hemolytic jaundice.

Physical examination revealed normal development. The child was extremely ill, lethargic, poorly nourished, and presented a definite icteric tint to the skin. The spleen was enlarged, extending 4 cm. below the costal margin, with a palpable notch along its medial border. No petechiae were observed. Sclerae were not jaundiced. Small cervical and axillary lymph nodes were palpable. Lungs were clear. Heart was negative except for an hemic systolic murmur heard at the apex, and a rate of 120. Blood pressure was 86/36. Nail beds were cyanotic. The icterus was not of obstructive origin. Erythrocyte count was 600,000 per cu. mm., hemoglobin level too low to be read, and there were nearly 100 per cent reticulocytes.

Oxygen was liberally administered, also two small intraperitoneal blood transfusions, during the next few days while observing the patient and arriving at a diagnosis. The temperature varied from 99° to 101.8° F. The jaundice was deepening. A diagnosis of congenital hemolytic icterus was made. An emergency splenectomy was performed September 16, 1933, by Dr. V. A. Dodd. The erythrocyte count immediately rose from 1,020,000 to 2,070,000 postoperatively. Two hundred cubic centimeters of citrated whole blood was infused into the peritoneal cavity before closing the abdomen. Supravital studies of the freshly removed spleen, made by Dr. Charles A. Doan, revealed the "pathognomonic picture of hemolytic icterus, engorgement of R. B. C. in 4-5 phagocytic clasmatocytes per oil immersion field. No P. M. N., monocytes, or epithelial cells."

Convalescence was stormy because of gastric atony and dilatation, that responded slowly to treatment, also, because of a transitory obstructive jaundice with clay-colored stools lasting three to four days and followed by spontaneous clearing. Patient left the hospital on October 19, 1933, her 32nd postoperative day, feeling fine, eating well, and with an erythrocyte level at 3,230,000 per cu. mm. Recovery was apparently complete.

Four years and four months later, the child, now nine years old, was readmitted, February 21, 1938, to the University Hospital. In the interim she had been periodically observed by Dr. Charles A. Doan, who found no recurrence of her disease until one month previously. At that time, January 21, 1938, definite hemolysis was observed, associated with return of the original symptoms. In the month preceding this second hospital admission, the erythrocyte count had fallen to 2,409,000, with the hemoglobin at 70 per cent, while the reticulocytes had risen to 39 per cent. A leukocyte count of 10,350, with an approximately normal differential for a nine-year-old child, and a platelet count of 1,727,000 were noted. After clinical study it was decided that the patient presented a recurrence of the hemolytic anemia. Therefore, it was deemed advisable to explore the abdomen and search for the accessory splenic tissue suspected of causing the recurrence. Accordingly, February 22, 1938, the abdomen was reopened by Dr. V. A. Dodd through a left paramedian incision. Two small accessory spleens were discovered in the retro-peritoneal tissue, over the tail of the pancreas, and were removed. In addition, biopsies of the liver and of the enlarged lymph nodes present in the mesentery and in the retro-peritoneal region, were taken.

Supravital studies of the accessory spleens by Dr. Charles A. Doan showed many highly phagocytic clasmotocytes engorged with red blood cells and engulfed pigment. The lymph node and liver sections revealed no excess of phagocytic elements.

Following the accessory splenectomy the patient made a gradual and persistent recovery, with subsequent rise of the circulating erythrocytes and fall of the reticulocytes. This patient, observed for two years afterwards, remained completely free from any evidence of recurrence of the congenital hemolytic icterus.

Thus, is presented a case of congenital hemolytic icterus that recurred subsequent to splenectomy. The recurrence was regarded as due to accessory splenic tissue not removed previously, the patient was explored, accessory spleens were found, removed, and the patient, thereupon, again recovered and remains symptom-free.

Certain questions may be raised, nevertheless, concerning the true nature of congenital hemolytic icterus. With two accessory spleens remaining, why was recovery apparently complete, and later, what was the pathogenesis of the reprecipitation of the disease? The second case report may be originally presented as follows:

**Case 2.**—V. M., female, age 21, was admitted to the University Hospital, September 4, 1942, a primipara seven months pregnant. She complained of bruising upon slight injury, bleeding gums, and intermittent fatigue of four months duration, starting during her third month of gestation. Petechiae and later ecchymoses appeared, first on the expanding abdomen and later upon the arms. Hematuria was noted three times during a 24-hour period during the third month of pregnancy. Epistaxis occurred occasionally. Three weeks prior to admission she vomited dark red blood, and was hospitalized for several days. Her past history and system review were otherwise essentially negative.

Physical examination revealed a well-developed, well-nourished young woman, age 21, lying quietly in bed. The enlarged abdomen of seven months pregnancy presented numerous petechiae and ecchymoses in addition to those over the extremities and back. The nose was bilaterally congested, with some bleeding from the right nostril. The pale oral mucosa showed evidence of recent bleeding. Tonsils were of moderate size. Mod-



erate lymphoid hyperplasia was present on the posterior pharyngeal wall. One right anterior cervical lymph node was slightly enlarged as was also one of the left supraclavicular group. Breasts were normal for the pregnancy. Chest was clear. The uterine fundus extended two fingersbreadth above the umbilicus. The fetal heart rate was 150. Reflexes were physiologic.

Laboratory data on admission showed a peripheral blood count of 9,050 leukocytes; 3,280,000 erythrocytes; and 6,519 platelets per cu. mm. The differential, by supravital technic, was P. M. N. 70 per cent, P. M. B. 2 per cent, small lymphocytes 4 per cent, intermediate lymphocytes 4 per cent, monocytes 4 per cent, and reticulocytes 7.8 per cent. The hemoglobin was 9.9 Gm. per cent (Newcomer). Three days later no platelets could be found in the peripheral blood. Supravital bone marrow studies showed adequate megakaryocytes with a fairly normal differential, revealing some left shift of both red and white cell elements, consistent with pregnancy. Urinalysis was negative. Serology was negative. Prothrombin time was 115 per cent, blood urea nitrogen 11.0 mg. per cent, blood sugar 78.4 mg. per cent, and blood chloride 564 mg. per cent. The feces showed blood, chemically and microscopically.

The patient was carefully investigated, and a diagnosis of primary thrombocytopenic purpura was made by Dr. Bruce K. Wiseman, who referred the patient for splenectomy. Preparation consisted of daily blood transfusions, two ampules of thyloquinone daily, and daily intramuscular corpus luteum extract, for a preoperative period of three days.

On September 9, 1942, under cyclopropane-oxygen with supplemental ether anesthesia, the abdomen was opened through a left rectus incision. The uterus, with its fundus high above the umbilical level, appeared quite characteristic. Fetal movements were discernible. The wound oozed considerable capillary blood. The characteristic small, purplish, apparently "normal" spleen of thrombocytopenic purpura was found moderately posterior in position, and attached by a short pedicle. Owing to technical difficulties resulting from the large pregnant uterus added to those encountered in a splenectomy of this type, the splenic pedicle was isolated, surrounded by the finger and thumb of the left hand and then clamped blindly. Due care was taken to exclude the stomach and tail of the pancreas. A second clamp was then applied, between the first and the hilus. The spleen was then luxated forward and removed by cutting between the two clamps. Hemostasis was secured by silk ligatures. An exploration for accessory spleens was then made, but none were found. Closure in layers was then accomplished using interrupted silk throughout. The patient left the operating room in excellent condition.

The pathologist, Dr. Harry L. Reinhart, reported the histologic picture as "compatible with thrombocytopenic purpura." There was a moderate hyperplasia of the reticulo-endothelial system, a decrease in the amount of lymphoid tissue, and considerable congestion.

Postoperative course was uneventful except for abdominal distention on the third postoperative day. This was relieved by continuous gastric suction. A fever, ranging preoperatively from 99.0° to 99.4° F. reached its peak, 100.8° F., on the day of operation, returning completely to normal range by the 11th postoperative day. There was no disturbance of the water or mineral balance or of kidney function. No evidence of increased uterine motility was manifest at any time. The patient steadily improved.

The postoperative hematologic recovery during her hospital stay consisted of the characteristic rise in peripheral platelets, from a preoperative range between zero and 12,520 per cu. mm. to an immediate postoperative rise within a few hours to 39,600 per cu. mm. This was followed by a gradual increase to 306,000 by the fifth postoperative day and subsequently to between 627,000 and 793,000 per cu. mm. during the last few days before dismissal. Peripheral erythrocytes varied from 3,280,000 on admission to 3,410,000 at the time of dismissal. Reticulocytes were 7.8 per cent on admission and 6.4 per cent on dismissal. Leukocytes showed no significant variation. A few days before dismissal an indirect van den Bergh was 1.1 mg. per cent, and the direct van den Bergh was delayed three minutes. The icteric index was 20. Clinically, the patient became

stronger and showed no further tendency to bleed. Her wound healed well. She was dismissed on the 19th postoperative day. Two months later she delivered at full term a normal baby girl. Both parturition and puerperium were quite normal.

Nearly two years later the patient, now 23 years old, was admitted, July 1, 1944, to the service of Dr. T. A. Spitler at the Findlay Hospital. She had been apparently quite normal since splenectomy, until a few days before this admission. She became tired and weak, and noted gingival and vaginal bleeding, together with epistaxis. Her pulse was regular and around 114, temperature 101° F., respirations 30, erythrocyte count 4,070,000, with 70 per cent hemoglobin; leukocytes 15,000, with 89 per cent neutrophils, 64 of which were nonsegmented, 11 per cent lymphocytes and 1 per cent myelocytes. The urine was brownish-red and loaded with red blood cells.

The next day she vomited dark red blood frequently, and was given 2,000 cc. of fluids intravenously. Temperature rose to 104° F., pulse to 126, and her respirations ranged in the thirties. A blood culture, taken after the patient began chilling, later proved negative. On July 3rd, numerous tarry, semiliquid stools were passed, and several chills occurred. She was then bleeding severely, the erythrocyte count by evening had fallen to 1,420,000, with 20 per cent hemoglobin. The leukocytes remained unchanged. The temperature decreased to 101.2° F., and the pulse became thready. Early the next morning, July 4th, the patient expired.

Necropsy was performed by Dr. T. A. Spitler. The stomach was distended, containing more than a quart of bloody fluid. The gastric mucosa presented myriad petechiae and several points of active bleeding. No ulcer was found. Liver was normal in size and shape. The spleen and appendix were both absent. There were hemorrhagic areas on the descending colon and along the small intestine. Two small nodular masses were found retroperitoneally, attached near the tail of the pancreas. These resembled accessory spleens, and consequently were sent to us, together with the other tissues, for further study and microscopic examination.

The pathologist to the University Hospital, Dr. Harry L. Reinhart, reported as follows: V. M., Autopsy No. 35983. *Gross.* The specimen consists of portions of ribs, the tail of the pancreas with two small accessory spleens attached, three lymph nodes, a portion of the liver and a portion of the kidney. Lymph nodes were slightly enlarged, measuring approximately 1 cm. in diameter. The accessory spleens are about 1.5 cm. in diameter. Other tissues are not remarkable.

*Microscopic.*—Spleen: Moderate enlargement of the accessory spleens, due largely to sinuses packed with monocytes and clasmatoocytes containing phagocytized pigment and other débris. Malpighian bodies present, also lacked protein and fibrinoid deposit. Lymph Node: Marked edema of lymphoid tissue, great dilatation of sinuses. Sinuses contain clasmatoocytes and monocytes actively engaged in phagocytosis of pigment, red cells, white blood cells and débris. Bone Marrow: Slightly hypoplastic. Large number of giant cells both mononuclear of the megakaryocytic type, and polynuclear of the osteoblastic type. There is also evidence of clasmatoocytic activity. Kidney: There is diffuse distribution of leukocytes around the tubules. Most of these appear eosinophilic. The cause is not apparent. Liver: Periportal collections of leukocytes and marked phagocytosis of blood pigment by the Kupffer's cells. Pancreas: No noteworthy pathology.

Thus, is presented the second instance of proved recurrence subsequent to this series of 174 splenectomies. Two accessory spleens were found at necropsy. Again, it appears that accessory spleens, if left behind, may cause eventual recurrence of primary thrombocytopenic purpura. To the reports of the infrequency of primary thrombocytopenic purpura occurring during pregnancy and the relative rarity of successful splenectomy during pregnancy for this disease,<sup>37</sup> this case may be added. Recurrence of symptoms subsequent to splenectomy occurred later during a pregnancy in several reported cases

and then disappeared after parturition. No direct observations of accessory splenic tissue could be made in these instances because of the vaginal route deliveries and the spontaneous postpartum recoveries from the thrombocytopenic purpura. The important facts of our case are the onset of the disease during pregnancy and the maintained recovery subsequent to splenectomy. Other reports have indicated recurrence of symptoms postsplenectomy, with a spontaneous recovery at its termination. The fact that recurrence did not appear in our patient during the remainder of the pregnancy in the known presence of accessory spleens suggests that there is no causal relationship in pregnancy upon the activation of primary thrombocytopenic purpura.

#### ACUTE INFARCTION OF THE ACCESSORY SPLEEN

Accessory spleens may become the seat of acute disease bearing no direct relation to the major spleen. Thus, torsion of the pedicle by which the accessory spleen is attached soon leads to severe circulatory disturbance and eventually necrosis. Settle<sup>38</sup> reports two such cases, both in children, four and eight years old.

#### ABBREVIATED CASE REPORTS (SETTLE)<sup>38</sup>

✓ **Case 1.**—A four-year-old male child presented severe abdominal pain with a distended, tympanitic and somewhat rigid abdomen. The point of greatest tenderness was in the left upper quadrant. Peristaltic waves were inaudible. The acute pain had been present for three days, with nausea and vomiting. Twenty-four hours after onset, chills, fever, and dehydration complicated the picture. Past history revealed that the child had occasionally cried out with abdominal pain during the two previous years. Temperature was 102.4° F., pulse 120, leukocytes 21,000, with 92 per cent P. M. N.

Upon opening the peritoneal cavity through a left rectus incision, eight hours after admission, 300 cc. of cloudy straw-colored fluid was found. Several loops of small bowel covered with fibrin, as well as the colon, were adherent to an orange-sized mass in the left upper quadrant. Kinking had produced obstruction of the small bowel. After dissecting away the loops of adherent bowel, an encapsulated tumor was found attached by a two-inch pedicle to the gastrosplenic ligament. The mass was quite soft, covered with fresh fibrin and its pedicle was in a state of advanced torsion. The mass was removed, and the major spleen observed to be normal in size, shape and position. Microscopic diagnosis revealed complete infarction of an accessory spleen.

**Case 2.**—This patient was an eight-year-old female child, with a less acute course. Epigastric pain with tenderness, greatest over left upper quadrant was noted. Localized moderate rigidity was present in this area. An indistinctly movable, tender, lemon-sized mass was palpable in the left upper quadrant. Leukocyte count was 13,000. At operation, an accessory spleen, with its pedicle in torsion and arising from the gastocolic ligament, was found and removed.

✓ Both patients made uneventful recoveries. Thus, an accessory spleen attached by a pedicle, which becomes twisted, may become hyperemic and infarcted, and cause an "acute abdomen," even with intestinal obstruction. The age-incidence in these two patients bears out the greater frequency of accessories in children.

#### SUMMARY

The end-result of splenectomy for congenital hemolytic icterus or primary thrombocytopenic purpura is influenced by whether accessory spleens which

may be present are found and removed. This was suggested in 1928 by Morrison, Lederer, and Fradkin for primary thrombocytopenic purpura. Subsequent observations, particularly of accessory spleens found in recurrences after splenectomy, have aided in establishing this conclusion.

The basic data upon which this report is made is presented as a list of the diseases for which 174 consecutive splenectomies and four abdominal explorations were done, and in tables showing the location of the 131 accessory spleens found in 56 of these patients. Further analyses are made. Significantly, the two most frequent indications for splenectomy, congenital hemolytic icterus and primary thrombocytopenic purpura, are the two diseases in which the accessory spleen, if present, must be removed along with the major spleen to prevent recurrence.

The incidence of accessory spleens reported by different observers is as follows:

11 per cent of all their necropsy material, by Adami and Nichols.

15 per cent of necropsies in children under age ten, by Sassuchin.

20 per cent in their first 35 splenectomies, by Curtis and White.

24 per cent in 13 splenectomies for congenital hemolytic icterus, by McLaughlin.

25 per cent of necropsies in children under age 17, by Jolly.

35 per cent of their necropsy material, by Morrison, Lederer, and Fradkin.

44 per cent in 18 splenectomies for essential thrombocytopenic purpura, by Maingot.

A greater incidence among the young has been generally noted.

In this series of 178 consecutive patients operated upon for various splenic diseases, 56, or 31.4 per cent, presented accessory spleens. The 50 per cent incidence in the first decade as well as the 39.1 per cent in the second decade is even greater than the increased incidence of accessories ordinarily found in the young with "normal" spleens. The decreasing incidence with advancing age is presumed to occur normally by gradual involution and atrophy. The onset of a pathologic process in splenic tissue apparently causes the accessory to remain and thus occurs the increased frequency of accessories in those with certain splenic diseases.

The greatest incidence of accessories was 57.1 per cent in the first decade in congenital hemolytic icterus. Forty-two point eight per cent were found in the second decade. In primary thrombocytopenic purpura 44 per cent were found in the first decade, and 33.3 per cent in the second decade. Save for the third decade, the incidence of accessories in congenital hemolytic icterus is greater than in primary thrombocytopenic purpura.

The number of accessories per patient varied from one to ten, 26 patients presenting but on accessory spleen. Single as well as multiple accessories occurred predominantly in the young.

The presence of splenules in great numbers, scattered throughout the peritoneum, appears to be a different clinical entity than true accessory spleens. Their occurrence is now known as *splenosis* (Buchbinder and Lipkoff). They

are to be differentiated because (1) they originate by transplantation of fragments of splenic tissue, usually scattered about the peritoneum by hemorrhage from a ruptured spleen; (2) they usually occur in great numbers, reportedly varying from 42 to 400; and (3) they are diffusely distributed throughout the peritoneum, even in areas where splenic tissue does not developmentally arise, as on the parietal peritoneum and ventral mesogastric layers.

The occurrence of splenosis is closely related to the technic of the usual splenectomy, since loose bits of traumatized splenic tissue may accidentally fall onto the peritoneal surfaces and become implanted. Such implants may develop and even result in the original splenic disease. Such may even prove to be the interpretation of one recurrence of congenital hemolytic icterus reported as due to compensatory hypertrophy of hemolymph nodes subsequent to splenectomy. Moreover, since splenic substance may even transplant to subcutaneous tissues, the incision should be protected during splenectomy in the event that the spleen is traumatized.

To avoid overlooking accessory spleens a routine search is made, after the major spleen has been removed, in the following approximate order: (1) Hilar region; (2) splenic pedicle; (3) retroperitoneal region surrounding the tail of the pancreas; (4) the great omentum and especially along its attachment to the greater curvature; (5) colic ligamentary attachments; (6) mesentery of both large and small intestines; and (7) in the female, the left adnexa.

In the 56 patients the 131 accessories were distributed in these locations according to the following percentages: Hilar, 54.2 per cent; pedicle, 25.1 per cent; omentum, 12.2 per cent; retroperitoneum, 6.1 per cent; splenocolic ligament, 1.5 per cent; and bowel mesentery, 0.75 per cent. In 85.7 per cent of the patients the accessories were found in but a single location. In no instance were accessories found in more than two locations in the same patient. In all instances of double location, the hilus constituted one location.

The embryologic background of accessory spleens, as well as their various locations, may be more clearly understood by considering five phases of splenic embryonic development: (1) The manner of formation of the major spleen, with its notches and lobulations, from separate splenic masses originating on the left side of the dorsal mesogastrium; (2) the formation of an accessory spleen by failure of fusion of splenic anlagen; (3) the formation and development of the subjacent dorsal mesogastrium into the various peritoneal ligaments and bursae, carrying along the accessory spleens to their various distant locations; (4) the development of the splenic artery and its branches, with similar distribution to both splenic lobules and accessory spleens; and (5) the embryonic contiguity of the splenic anlagen to the genital ridge, thus, permitting an accessory spleen to become attached to the left gonad and to descend with it into the pelvis or scrotum.

Four instances of recurrence subsequent to splenectomy are presented. In all, accessory spleens were found and appeared to be the cause. Two cases from the literature are briefly summarized. They are the original observations of Morrison, Lederer, and Fradkin, and of Watson and Moir, both

patients having primary thrombocytopenic purpura. The two recurrences thus far observed in our series of 174 consecutive splenectomies are reported in detail, one with primary thrombocytopenic purpura and the other a striking case in which recurrence of congenital hemolytic icterus was relieved by removal of two accessory spleens at a second operation.

Finally, pedunculated accessory spleens may cause acute abdominal symptoms from infarction due to pedicle torsion. This is shown in a summary of two such case reports.

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# BILIARY ASCARIASIS

## REPORT OF 19 CASES

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ASCARIASIS is one of the most common, if not the most common, helminthic infestation of man. In Szechuan, Chang and Ch'in<sup>1</sup> found 90 per cent of seven different rural population groups infested. In the Philippines various groups range from 40 per cent to 83 per cent infested.<sup>5</sup> It is widespread in many tropical, subtropical, and even temperate zones. Accordingly, ascariasis, as such, has received considerable attention. Yet its very commonness has led to a certain attitude of benign tolerance and even indifference on the part of the medical profession. It is all too rarely realized that ascariasis is a dangerous disease. Even in comprehensive works on tropical disease its dangers are not emphasized. For example, reference to biliary ascarides, by Stitt and Strong,<sup>2</sup> is limited to the following: "They may penetrate into any accessible passage or space and cause bizarre and sometimes serious local disturbances; *e.g.*, into the appendix, bile ducts, gallbladder, pancreatic duct, nose, sinuses, middle ear and larynx. . . . Rajahram has reported the case of a girl of six who died with five ascaris-containing abscesses in her liver." Manson-Bahr<sup>3</sup> dismisses biliary ascarides with: "They have been known to enter the bile ducts and give rise to jaundice and abscess of the liver."

That ascarides can invade many diverse organs and areas of the body, giving rise to many diverse and at times fatal conditions, is attested by isolated reports which can be found in the literature. A survey of the Quarterly Index Medicus from 1930 to 1943, inclusive, reveals 30 articles on the subject of biliary ascariasis from all parts of the world. All but Crowell's<sup>5</sup> report concern only isolated instances of one or two cases.

Muir<sup>6</sup> reported a Chinese case of an ascaride in the common bile duct and gallbladder. He quotes Aviles as having collected 90 cases of ascariasis of the common duct from the literature up to 1918. A more comprehensive report on the dangers of ascariasis was made by Crowell<sup>5</sup> in 1920. He states "migration of the ascaris into the common bile duct and thence into the gallbladder or into the intrahepatic bile ducts is a frequent occurrence, and must be much more frequent than is indicated by the reported cases, as the diagnosis is made only at operation or at autopsy." He reports 12 autopsy cases of ascariasis of the bile ducts and liver, six of them associated with liver abscess and two with pancreatic duct obstruction and pancreatitis. These cases were observed in the Philippines.

In 1928, Morton<sup>8</sup> found eight reports of ascariasis of the gallbladder and



reported one case from Virginia. He emphasized two features: First, an history of ascariasis; and second, biliary tract disease.

In 1933, Ch'in<sup>7</sup> reported a case of acute hemorrhagic pancreatitis due to *ascaris lumbricoides* impaction in the ampulla of Vater, and listed 28 references to biliary or pancreatic ascariasis. In 1936, he reported a case in which ascariasis of the liver caused fatal hemorrhage both into the biliary tract and thence into the gastro-intestinal tract, and directly into the free peritoneal cavity.

Three cases of biliary ascariasis were reported from Szechuan by Chen,<sup>4</sup> in 1943. Two of these were autopsy cases, one presenting purulent cholangitis with liver abscess, the other showing fossilization of ascarides in the liver. The third case was a clinical case which we report here in further detail as Case No. 1.

The present communication deals with 19 cases of biliary ascariasis observed in the United Hospitals of Chengtu during the past three years. Twelve of the 19 cases have been seen in the past 18 months, suggesting perhaps that as the condition is more carefully sought for it may prove to be even more common than herein indicated.

#### CASE MATERIAL

Table I provides a brief abstract of 14 of our cases. All but one were under 28 years of age. All but two were Szechuanese, and those two had lived in Szechuan for over two years. Four were males, ten female. All complained of rather severe epigastric and/or right upper quadrant pain except one (No. 9) who had severe epigastric and left upper quadrant pain. As more of these cases were seen we came to feel that there might be a characteristic distending type of pain present in contrast to the stabbing, knife-like pain of cholelithiasis. One patient (No. 8) even stated that he thought something was crawling around inside him. All but three complained of vomiting. The symptomatology in general suggested cholecystitis. Five were jaundiced, although those seen early in their illness tended not to be jaundiced. Epigastric and right upper quadrant tenderness and spasm were common, although the one (No. 9) who had left upper quadrant pain also had left upper quadrant tenderness. The temperatures tended to be low, especially in the cases seen during the first day or two of illness. All but Cases 9 and 12 had stools positive for *ascaris* ova. Eleven had a past history of ascariasis. Ten had had previous similar attacks. All underwent operation, four with the correct préoperative diagnosis, and three with biliary ascariasis as a suggested possibility. The remainder were diagnosed cholecystitis and/or cholelithiasis, except for one case diagnosed liver abscess. Three had acute cholecystitis. Four had distended gallbladders. Five had tense, firm common ducts with a typical catheter-like consistency. Through the wall of the tense duct the white ascaride could be visualized as a light streak. In these cases aspiration yielded only a few drops of bile, if any, and even on incising the common duct no bile escaped in several instances. Six had

dilated common ducts, and in the rest the operative descriptions were inadequate. All had ascarides in the common duct. Typically, about one-third of a 20-cm. ascaride projected into one of the hepatic ducts from the site of choledochotomy, while the remaining two-thirds of the ascaride, the caudal two-thirds, extended down the common duct into the duodenum. In Cases 5, 7, and 14 ascarides were also partly, or completely, in the gallbladder. All had choledochotomy except in the liver abscess case, who had incision and drainage only, and Case 5 in whom the worm was manually expressed out of the common duct during celiotomy. Seven choledochotomies were used as choledochostomies by T-tube drainage, while choledochotomies were primarily closed without drainage in four instances. In Case 2 an additional ascaride crawled out alongside the T-tube on the tenth post-operative day. In Case 8 a ring-like impression was noted at about the junction of the middle and caudal thirds of the ascaride suggesting the impress of a spastic sphincter of Oddi. In Case 2 the doubling-up of the worm in a dilated common duct, with head and tail in the lower duct, suggests that at times the worm may enter and leave the duct spontaneously. Two deaths occurred, one due to pericholecystic abscess, peritonitis, and *Friedländer bacillus* septicemia; another due to multiple liver abscesses. All other patients were treated with anthelmintics as soon after operation as their conditions permitted.

COMMENT: The predilection for ascarides to enter any available aperture is well known. At times they have been found projecting through holes in glass beads or buttons inadvertently swallowed. In other instances the appendix may harbor the worm. Crowell<sup>5</sup> reports a case in which an ascaride burrowed between two adjacent tuberculous intestinal ulcers.

When apertures are not available the adult worm may burrow through tissues to the free peritoneal cavity, into the urinary bladder, or elsewhere. In one local case a deep thigh abscess harbored an ascaride, while in another instance an orbital abscess contained an ascaride.

In this report attention is called to the relative frequency of ascarides in the bile ducts and gallbladder, and to the serious consequences which ensue. It is urged that the disease be regarded with greater respect, and that its dangerous potentialities be recognized. Patients known to harbor the parasite should be vigorously treated before complications develop. Where infestation is widespread, mass therapy is indicated.

In such areas the condition should be suspected in patients presenting symptoms of cholecystitis or common duct obstruction. In these cases adequate preoperative preparation followed by surgical intervention is indicated. Such cases also would seem to be further justification for early surgical treatment as opposed to conservative therapy.

#### SUMMARY AND CONCLUSIONS

Nineteen cases of biliary tract ascariasis are presented and discussed,

together with excerpts from the literature, to lend support to the contention that ascariasis is a dangerous disease.

If in an endemic area a young person below the usual age for cholelithiasis presents symptoms and signs of biliary tract disease, biliary ascariasis should be suspected. If, in addition, the stool is positive for ascaris ova; there is a recent past history of ascariasis; the patient has recently vomited ascarides; there is an history of previous similar attacks; and the pain has a peculiar distending quality—then the diagnosis of biliary ascariasis can be made with reasonable certainty.

Since the submission of this article for publication, five more instances of biliary ascariasis have been operated upon, and may be added to the 14 summarized in Table I.

#### FIVE ADDITIONAL CASE REPORTS

**Case 15.**—Hosp. No. 5012—1945: A 35-year-old Szechuanese woman complained of right upper quadrant and epigastric pain of colicky nature for 18 hours preceding admission. Vomited undigested food several hours after onset of pain, but no ascarides. Past history of vomiting ascarides two years before, but no previous similar attacks. Acutely ill, writhing with pain. No jaundice. Epigastric and right upper quadrant pain and tenderness, with spasm. Temperature 100.4° F.; W. B. C. 12,000. Stool positive for ascaris ova. *Preoperative Diagnosis:* Biliary ascariasis.

*Operative Findings:* G. B. hugely distended, thickened, neck bound down by adhesions to omentum and duodenum. C. D. dilated to 1.5 cm., not thickened, but two cord-like ascarides palpable in C. D. Two adult ascarides removed through choledochotomy incision, one worm being doubled upon itself. Cholecystectomy and choledochostomy. Uneventful recovery.

**Case 16.**—Hosp. No. 5193—1945: A 40-year-old Szechuanese woman complained of epigastric pain, severe and colicky, for four days preceding admission. Vomited undigested food, but no ascarides, the day of admission. Past history of vomiting ascarides several years previously, and repeated similar attacks of epigastric pain for 20 years. Acutely ill, doubled-up with pain. No jaundice. Epigastric and right upper quadrant tenderness and spasm. Temperature 99.4° F.; W. B. C. 4,700. Stool positive for ascaris ova. *Preoperative Diagnosis:* Chronic cholecystitis, with cholelithiasis. Suspected biliary ascariasis.

*Operative Findings:* Greatly dilated G. B., measuring 12 x 13 x 7 cm. Wall somewhat thickened. No stones palpable. C. D., 1 cm. in diameter, not thickened. An ascaride was seen wriggling within the C. D. It was also palpated. Another was palpated in the duodenum. The C. D. was opened and the ascaride previously seen and palpated had disappeared. After some investigation it was found high in the hepatic ducts and withdrawn. It measured 19 x 0.3 cm. During this period the patient vomited a 28-cm. ascaride, after which the duodenal ascaride was no longer palpable. Cholecystectomy and choledochotomy. Death on fourth postoperative day—clinically due to bilateral pneumonia. Autopsy permission refused.

**Case 17.**—Hosp. No. 5509—1945: The patient was a 40-year-old Szechuanese woman, complaining of severe colicky epigastric and right upper quadrant pain radiating to the right scapula, for four days. N and V present, but no ascarides vomited. No jaundice. Had repeated similar attacks for 20 years, with jaundice. Had ascarides in stool within past six months. Acutely ill, doubled up with pain. No jaundice. Direct tenderness epigastrium and r. u. q., no rebound tenderness, gallbladder questionably palpable, Murphy's sign positive. Moderate r. u. s. spasm. Temperature 99° F.; W. B. C.

## BRIEF ABSTRACT OF 14

Case No.	Hosp. No.	Age	Sex	Province	Onset of Illness	First Symptoms	Other Symptoms	History of Ascariasis	Other History	Jaundice
1	15429 '42	18	M	Szechuan	12 hours	Severe epigastric pain; n & v	Paroxysmal colicky pain radiating to the r.u.q.	Vomited ascarides 4 yrs. prev.	3 similar prev. attacks	
2	18593 '43	19	F	Szechuan	26 hours	Severe epigastric pain; n & v	Paroxysmal colic, sweating and dizziness	Passed ascarides repeatedly	1 similar attack 3 mos. prev.	
3	18938 '44	18	M	Szechuan	19 days	Fever and chilly sensations	Severe epigastric and r.u.q. pain, n & v, 5 days	Not recorded	Recurrent abd. pain since age 6	
4	2840 '44	23	F	Szechuan	4 hours	Severe epigastric and r.u.q. colic	Radiation to rt. back; n & v	Passed ascarides several months previously	Neg.	
5	19178 '44	46	F	Szechuan	3 days	Severe r.u.q. colic	Vomited 20 ascarides; chilliness and fever	Vomited ascarides many times in past	Many similar prev. attacks, with jaundice	
6	19839 '44	26	M	Szechuan	4 days	Fever and headache	Severe epigastric and r.u.q. pain 20 hours	Ascarides passed in childhood	One similar prev. attack	
7	20128 '44	15	F	Szechuan	40 days	Epigastric pain; vomited ascarides	Subsidence after 6 days; recurrence 10 days prev. to adm.	Neg.	Occ. prev. attack	
8	4095 '44	22	M	Hunan; 2 yrs. in Szechuan	2 days	Severe epigastric and r.u.q. pain	Vomiting; fever	Passed ascarides in recent years	Neg.	
9	4600 '45	19	F	Hupei; 6 yrs. in Szechuan	20 hours	Chill followed by fever	Severe epigastric and l.u.q. pain, vomiting, 1 hour	Neg.	Neg.	
10	4696 '45	24	F	Szechuan	10 days	Nausea and vomiting of ascaride	Epigastric and r.u.q. pain, 5 days	Passed and vomited ascarides many times prev.	Many similar prev. attacks	
11	4794 '45	13	F	Szechuan	1 day	Severe epigastric pain	Vomiting 6 hrs.	Passed and vomited ascarides many times	Many similar prev. attacks	
12	21939 '45	23	F	Szechuan	2 mos.	Acute epigastric colic; chills, fever; productive cough	Severe vomiting 2 mos. Distension, edema. Epigastric mass	Repeatedly passed ascarides	Occ. prev. attacks	
13	22240 '45	11	F	Szechuan	3 days	Epigastric and r.u.q. colic	Vomited 20 ascarides	Repeatedly vomited ascarides	Occ. prev. attacks	
14	22324 '45	27	F	Szechuan	8 hours	Severe r.u.q. colic radiating to rt. back	Chilliness and headache for 5 days	Passed ascarides repeatedly	Neg.	



9,000. Stool 1+ for ascaris ova. *Preoperative Diagnosis*: Cholelithiasis, with chronic cholecystitis and hydrops of gallbladder. Suspected biliary ascariasis. *Operative Findings*: G. B. greatly dilated 15 x 9 cm., not acutely inflamed. C. D. dilated, 2 cm., not thickened. Ascaride palpable in upper C. D., on choledochotomy, found doubled up with both ends extending into hepatic ducts, central portion just above choledochotomy incision. On removal measured 26 x 0.5 cm. Also some cystic and C. D. sand. *Operation*: Cholecystectomy and choledochostomy. Uneventful recovery.

**Case 18.**—Hosp. No. 23167—1945: The patient was a 14-year-old Szechuanese boy, complaining of severe colicky epigastric and right upper quadrant pain of eight hours duration. N and V present, patient vomited three times, but no ascarides were noted. No jaundice. Had repeated similar previous attacks for two years. No ascarides had been passed previously. Moderately ill. Direct tenderness in epigastrium and r. u. q., with positive Murphy's sign. Temperature 100° F.; W. B. C. 10,450. Stool 2+ for ascaris ova. *Preoperative Diagnosis*: Biliary ascariasis. *Operative Findings*: G. B. normal. C. D. 1 cm. in diameter, and containing an adult ascaride, about 20 cm. in length. *Operation*: Choledochostomy. Uneventful recovery.

**Case 19.**—Hosp. No. 5600—1945: A 26-year-old Szechuanese male entered complaining of severe epigastric pain, cramp-like and colicky, of 16 hours duration. Vomited eight times, but no ascarides noted. No jaundice. Similar attacks in childhood. Ascariasis in childhood. Moderately ill, occasionally doubling-up with severe pain. Right epigastrium tender. Liver edge descends 1.5 cm. on inspiration, and is tender. No rebound tenderness or spasm. Temperature 98.6°–100° F. Stool negative for ova. W. B. C. 10,700. *Preoperative Diagnosis*: Suspected biliary ascariasis. Observed and rehydrated for 18 hours, during which time there was no improvement in symptoms. *Preoperative Diagnosis*: Biliary ascariasis. *Operative Findings*: G. B. moderately dilated to 10 x 6 cm. G. B. wall somewhat thickened. C. D. normal in appearance, about 1.0 cm. in diameter; but an ascaride was palpable and faintly visible therein. On removing the ascaride, the head was found projecting into the hepatic ducts, the tail down toward the sphincter of Oddi. The ascaride measured 20.5 x 0.3 cm. *Operation*: Choledochotomy, cholecystectomy. Uneventful convalescence.

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# SYMPATHECTOMY FOR ISCHEMIA FOLLOWING FEMORAL ARTERY LIGATION

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IN VIEW of the current interest and lack of agreement in the value of sympathectomy following ligation of the femoral artery, the following five cases are reported. The cases are similar in that all had the superficial femoral artery and vein ligated between the profunda femoris branch and Hunter's canal. The first case was observed for three months then sent to limited duty without sympathectomy. In three cases sympathectomy was performed after a two months observation period. The fifth case had a sympathectomy immediately following the ligation of the vessels.

Dr. I. A. Bigger, in a recent article,<sup>1</sup> points out the frequency of permanent reduction of blood supply to tissues, especially the muscles, following interruption of large arteries. He reports seven out of eight cases with interruption of the main artery of the lower extremity (iliac to popliteal) had definite symptoms of chronic circulatory deficiency distal to the obstruction on examination after a period of nine months to eight years. One case which did not have these symptoms had had an injection of the lumbar sympathetic ganglia with alcohol.

## CASE REPORTS

**Case 1.**—A 24-year-old Ordnance Sergeant was wounded in action, March 16, 1944, at 0700 hours, at Anzio Beachhead in Italy, sustaining a penetrating wound of the left thigh from enemy shell fragments. The fragment divided the femoral artery and vein at the proximal end of Hunter's canal. He received 1 cc. of tetanus-toxoid and sedation at the Battalion Aid Station and was then sent to an Evacuation Hospital. At 1000 hours, March 16, 1944, three hours after injury, the wound was débrided and the femoral artery and vein ligated at the site of injury. A lumbar paravertebral sympathetic injection with novocaine was done on the 16th and 17th of March. Forty thousand units of gas gangrene antitoxin was given intramuscularly. A plaster hip spica encasement was applied for the immobilization of the soft-tissue wounds and the patient evacuated to a General Hospital March 23, 1944.

On March 24, the toes were fairly warm but no pulsations could be felt in the foot; the color was good, however, and there was no swelling. There were two large wounds, anterior medial and the lateral surface of the thigh with some induration of the exposed muscle. On March 24, 1944, a transfusion of 500 cc. of blood was given and the following day the plasma protein was 8.3 Gm.; hemoglobin 15 Gm., and hematocrit 44 per cent.

On March 27, 11 days after the débridement, the wounds were closed with end-on-mattress silk sutures after trimming the skin edges.

*Progress Notes*—April 5: "Sutures removed, the wounds are healing cleanly."

April 11: "Posterior tibial pulse cannot be felt. The dorsalis pedis is present but weak. The toes are normal color, there is no swelling, the left foot is slightly cooler than the right."

April 24: "There is a small area on the left heel which has purplish discoloration and a vesicle has formed, probably the result of pressure from the splint. He has been walking fairly well."

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May 11: "The area on the left heel has almost covered over with epithelium now. The posterior tibial and dorsalis pedis pulses are present but weak. The left foot is cooler than the right on cool days and the color of the foot is normal."

June 1: "It is now three months since the injury and ligation of the vessels. The vessels of the involved foot can be felt but pulsate weakly. On cool days the pulsation cannot be felt and there is a difference in the temperature of the two feet. The color is normal and there is no swelling. He does not have excessive sweating of the feet. The calf cramps after walking 800 to 1,200 yards at a moderate rate of speed."

*Disposition:* Sent to limited duty in the Mediterranean Theater.

**Case 2.**—A 23-year-old Infantry Private was accidentally shot by another soldier, at 2030 hours, May 15, 1944, at Anzio Beachhead in Italy. He was given 1 cc. of tetanus toxoid and 250 cc. of plasma at the Battalion Aid Station, then was taken to a Field Hospital. At 0100 hours, May 16, 1944, 4.5 hours after injury, the wound was débrided and the left femoral artery and vein ligated in the mid thigh, distal to the profunda femoris branch. Lumbar sympathetic novocaine injections were done daily for three days. Sulfadiazine, 1 Gm. every four hours was given orally following the operative procedure. On May 23, the wounds were sutured under local novocaine anesthesia. He was evacuated to a General Hospital, May 26, where examination showed the wounds to be healing cleanly. The left foot was cooler than the right and both feet were sweaty. The pulsations could not be felt in the left foot vessels. There was no swelling of the foot and the color was good. The plasma protein was 6.6 Gm., hemoglobin 11.8 Gm.; hematocrit 34.5 per cent.

*Progress Notes.*—May 29: "Transfusion 1,000 cc. of whole blood."

June 20: "Cold day, both feet cold and moist, pulses in the left foot are not palpable, color slightly cyanotic."

July 8: "The posterior tibial pulse can now be felt. The dorsalis pedis is very weak. The feet are about the same temperature, both sweaty and cold. He can walk about 400 yards slowly without pain but gets cramp in the calf on climbing two flights of stairs at moderate speed."

July 31: "(Cool day) The left foot is cooler than the right, both are sweaty and he can walk only 200 to 300 yards at moderate speed before getting pain in the left calf (two and one-half months after injury)."

August 10: "Left lumbar sympathectomy performed under spinal anesthesia, through an anterior muscle-splitting extraperitoneal approach. The second and third lumbar ganglia and connecting sympathetic trunk were excised."

August 26: "The abdominal wound healed cleanly. He can walk ten times the distance he could prior to sympathectomy at the same rate of speed without cramping in the calf (16 days after operation)."

September 20: "He walked one and one-fourth miles today at a brisk pace without pain (one month and ten days postoperative)."

"The foot and leg are warm and dry, there is no swelling, and the left foot is warmer now than the right. The posterior tibial pulse is fairly strong."

*Disposition.*—Limited duty in the Mediterranean Theater four months after injury and one month and ten days after sympathectomy.

**Case 3.**—A 26-year-old Infantry Private sustained multiple penetrating wounds by enemy shell fragments, at 0800 hours, June 1, 1944, near Rome, Italy. He received 250 cc. of plasma and 1 cc. of tetanus toxoid at the Battalion Aid Station, and was then sent to a Field Hospital where, at 1320 hours, June 1 (five and one-half hours after injury) the wounds were débrided. There was extensive muscle destruction of both anterior thighs, especially the left, and the left femoral artery and vein had been severed distal to the profunda femoris branch. The vessels were ligated and plaster splints applied to both lower extremities for soft-tissue immobilization. He was evacuated to a General Hospital, June 6, 1944, where examination showed extensive wounds of both anterior thighs with some necrotic tissue in the wounds. The pulses of the left foot



could not be felt, the color was pale, there was no swelling and the left foot was slightly cooler than the right.

*Progress Notes.*—June 7: "Plasma protein 6.6 Gm.; hemoglobin 9.2 Gm.; hematocrit 27 per cent.

June 8: "Transfusion 1,000 cc. of whole blood."

June 9: "Transfusion 1,000 cc. of whole blood. Wounds closed after excising the necrotic tissue from the thigh wounds and mobilizing skin flaps by undercutting. Drain left in right thigh wound. Penicillin 25,000 cc. every three hours, given from June 8 until June 13."

June 11: "Plasma protein 7.3 Gm.; hemoglobin 13.7 Gm.; hematocrit 40.5 per cent."

June 20: "Sutures removed, moderate purulent reaction about sutures and small deep pocket of pus at upper angle of left thigh wound. Hot dressings applied."

June 27: "Wounds healing satisfactorily."

July 12: "Patient walking about and getting physiotherapy. He has marked weakness of muscles of both thighs but the left is more marked than the right."

August 1: "(Two months after ligation of artery.) The left foot is cooler than the right and the left foot pulses are weak. He has cramping pain in the left calf after walking up two flights of stairs at a moderate speed."

August 10: "(Two and one-half months after injury.) Left lumbar sympathectomy performed through an anterior muscle-splitting abdominal incision using the extra-peritoneal approach. The second and third lumbar ganglia and connecting trunk were excised. (Spinal anesthesia.) Some enlarged lymph nodes were encountered in reflecting the peritoneum over the sympathetic chain."

August 13: "Temperature elevated to 102–103° F. Pain and tenderness deep in left flank. The wound was explored under pentothal anesthesia. Moderately large collection of thin, bloody purulent exudate in retroperitoneal space evacuated. Two drains (cigarette) inserted. Culture of fluid showed *beta hemolytic Streptococci*. Penicillin 25,000 units every three hours and sulfadiazine 3 Gm. followed by 1 Gm. every four hours started."

August 17: "Temperature and pulse have gradually declined. The left foot has been dry and warmer than the right since the sympathectomy, color of foot is normal. Posterior tibial pulse fairly good volume, no swelling."

September 3: "Temperature elevated again, and some pain in the left flank. Digital exploration, under pentothal anesthesia, revealed small pocket beneath fascia with inadequate drainage."

September 16: "Patient afebrile, wound healing, drain removed."

October 7: "Sympathectomy wound almost healed now, the patient is taking daily walks with gradual improvement. He has considerable general weakness from sepsis and long hospitalization, plus local weakness of the thigh muscles from muscle destruction by the fragments."

October 11: "The posterior tibial and dorsalis pedis pulses are palpable and strong on left. The left foot is dry and warmer than the right. There is no swelling and the color is normal. He can walk 1,200 yards at a moderate speed. General weakness and local weakness in thigh prevent further walking now. No pain experienced in the left foot after walking this distance, also no pain after walking up stairs."

*Disposition.*—Evacuation to Zone of Interior (four and one-half months after injury, two months after sympathectomy).

Case 4.—A 28-year-old Infantry Sergeant was wounded in action by enemy bullet, at 2400 hours, August 19, 1944, in Southern France, sustaining penetrating wounds in the hip, left thigh, and right heel with laceration of the right femoral artery and vein. He received 1 cc. of tetanus toxoid and 750 cc. of plasma at the Battalion Aid Station at 0120 hours. The patient was then sent to a Field Hospital where the wounds were débrided and the femoral vessels divided and ligated at the site of injury below the

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profunda femoris branch. The exact time was not stated, but was probably within a few hours after the injury, on August 20, 1944.

Lumbar sympathetic injections of novocaine were done daily for three days. Penicillin 15,000 cc. every three hours was given intramuscularly. He was evacuated to a General Hospital in Italy, on August 25, at which time he was quite pale; plasma protein was 6.7 Gm.; hemoglobin 8.2 Gm., and hematocrit 24.1 per cent. The pulses could not be felt in the right foot, the foot was pale and slightly cyanotic and cooler than the left foot. There was no swelling.

*Progress Notes.*—August 25: "Transfusion 1,000 cc. of whole blood."

August 26: "Transfusion started, after receiving about 100 cc. he had a severe reaction, with back pain, numbness, and tingling of extremities, dyspnea, cyanosis, but symptoms were relieved by adrenalin. Cross-match rechecked and found compatible. Reason for the reaction not determined."

August 27: "Wounds closed (seventh day after débridement). Transfusion 1,000 cc. of whole blood during operation."

September 3: "Sutures removed, wounds healing cleanly."

October 2: "(Two months after injury) patient has cramping pain in right calf after walking 500 to 600 yards at moderate speed. The pulses remain weak, and the foot becomes quite cold and pale on cold days."

October 28: "Right lumbar sympathectomy. Spinal anesthesia, extraperitoneal, muscle-splitting, anterior abdominal incision. The second and third ganglia and connecting trunk were excised."

November 6: "The right foot has been dry and warmer than the left since sympathectomy. Pulses in foot fairly good volume. Suture removed. Wound healing clearly."

November 13: "Taking daily walks. No cramping in calf."

November 25: "(Three months after injury, one month after sympathectomy.) Patient can now walk two miles at a moderate speed without pain in the calf. The right foot remains dry and warmer than the left. There is no swelling. The color is good and the pulses of good volume."

*Disposition.*—Limited duty in Mediterranean Theater.

**Case 5.**—A Sergeant in a Tank Battalion was wounded by accidental explosion of a rifle grenade on a practice range in Northern Italy, at 1530 hours, February 14, 1945, sustaining a penetrating wound of the left anterior thigh. There was considerable bleeding from the wound, necessitating the application of a tourniquet. Treatment during evacuation consisted of the application of a dressing and the injection of one-quarter grain of morphine. He was given 1 cc. of tetanus toxoid and penicillin started. The left foot was cold and pulseless.

*Operation.*—February 14, 1945, 2000 hours: Under gas-oxygen-ether anesthesia, the wound was débrided, the femoral artery was found divided about three centimeters below the profunda femoris branch. The vessel was ligated and the concomitant vein divided and ligated at the same level. The metallic fragment was removed. The wound was left open. A dry fine-mesh gauze dressing was applied.

At the end of the above procedure the left foot was cold, pulseless and a cyanotic-purplish color. The general condition of the patient was good. A left lumbar sympathectomy was then done through an anterior muscle-splitting extraperitoneal approach. Lumbar ganglia II and III with connecting trunk were removed. The wound was closed in layers with fine cotton. Following the sympathectomy the left foot was almost as warm as the right. The veins were full and showed good venous flow. The color was slightly cyanotic but gradually became normal within a few hours. A 1,000 cc. blood transfusion was given during the operation.

*Progress Notes.*—February 15: "The left foot is hot and dry, veins full good color. Feet about equal warmth. No pulse is felt in the left foot. Plasma protein 6.2 Gm.; hemoglobin 11.2 Gm.; hematocrit 38 per cent."

February 16: "Transfusion 500 cc. of blood given. Patient has moderate tenderness and some pain on motion in left medial calf muscles."

February 20: "Patient is afebrile for two days now. Wound of left anterior thigh closed with end-on-mattress silk sutures, under pentothal anesthesia."

February 24: "Penicillin discontinued. He has been afebrile since February 21."

February 28: "Abdominal and thigh wounds are healing cleanly. All sutures have been removed."

March 14: "Plasma protein 6.5 Gm.; hemoglobin 15 Gm.; hematocrit 44 per cent."

"It is now one month following injury and operation. He has been taking daily walks and thigh exercises. Today he walked two and one-half miles on a one-quarter mile measured track at a moderate gait without experiencing cramping in the leg. He does have cramp in the calf after walking one-quarter mile at a very fast pace. The foot remains dry and warm. The posterior tibial pulse can be felt on the left. The dorsalis pedis is not palpable."

*Disposition.*—Evacuated to a General Hospital, and from there was sent to duty in the Mediterranean Theater.

*DISCUSSION.*—The inaccessibility of a medical library prevents review of the literature on this subject. White and Smithwick<sup>2</sup> make the following statement about sympathectomy upon patients with arteriosclerosis and thrombo-angiitis obliterans who have associated vasospasm: "Besides improvement in the circulation to the skin and subcutaneous tissue, muscular circulation may also occasionally benefit, as judged by improvement in or disappearance of intermittent claudication."

The common stimuli which cause vasoconstriction are cold, pain, fear, anger, asphyxia, hemorrhage and dehydration. In any but the warmest climate, and under the most ideal circumstances, one is apt to experience many of these stimuli during peacetime as well as in a War Theater. In three cases the effect of cold stimulus could be seen repeatedly before sympathectomy.

The number of cases presented is too small to attempt to draw any broad conclusions from them. The results do, however, indicate that the recovery can be hastened and is probably more complete, with less disability resulting in those cases having sympathectomy performed following the division of the femoral artery.

#### SUMMARY

Five cases are presented, all of which had ligation of the femoral artery and vein between the profunda femoris branch and Hunter's canal. All cases were between the ages of 20 and 30 years. All cases had intermittent claudication in the calf of the involved extremity after walking a short distance at a moderate speed. The greatest distance any patient could walk at this speed was 800 to 1,200 yards prior to sympathectomy. The average distance of the four observed two months or more following ligation of the vessels was 500 to 600 yards. One case having sympathectomy immediately after ligation of the vessels walked two and one-half miles, over a measured course at a moderate rate of speed, one month following the operative procedures.

# SYMPATHECTOMY FOR ISCHEMIA

TABLE I  
SUMMARY OF DATA ON 5 PATIENTS UPON WHOM SYMPATHECTOMY WAS PERFORMED FOR ISCHEMIA

Case No.	Date of Injury	Age	Time-Interval between Injury and Ligations of Vessels	Immediate Postoperative Novocaine Lumbar Sympathetic Injection	General Supportive Measures—Oxygen, Blood, Position, etc.	Hematocrit	Distance Walked at Moderate Speed before Cramping in Calf Occurred	Time-Interval between Ligations of Vessels and Sympathectomy	Distance Walked Following Sympathectomy at Moderate Speed	Disposition
1.	16 March, 1944	24	3 hours	Yes, for 2 days	None immediately. Postoperative transfusion 500 cc. blood, 24 March, 1944	44.5%, 24 March, 1944	800-1,200 yards, 3 months after injury	Sympathectomy not done		Limited duty 3 months after injury
2.	15 May, 1944	23	4.5 hours	Yes, daily for 3 days	None immediately. Postoperative 1,000 cc. blood transfusion, 29 May, 1944	34.5%, 28 May, 1944	200-300 yards, 2.5 months after injury	2.5 months	Walked 1.25 miles without cramping, 1 month and 10 days after sympathectomy	Limited duty 4 months after injury
3.	1 June, 1944	26	5.5 hours	None recorded	Plasma 500 cc. prior to operation. 2,000 cc. blood transfusion, 8 June, 1944	27%, 7 June, 40%, 11 June	After walking up 2 flights of stairs, 2 months after injury	2.5 months	1,200 yards without cramping. Muscle loss in thigh prevented further walking (See case report)	Evacuated to Z.I.
4.	19 August, 1944	28	Time not stated. (Less than 24 hours)	Yes, daily for 3 days	750 cc. of plasma at Bn. Aid Sta. Transfusion 1,000 cc. blood, 25 August, 1944. Transfusion 1,000 cc. blood 27 August	24.1%, 25 August, 1944	500-600 yards, 2 months after injury	2 months	2 miles at moderate speed without pain, 1 month following sympathectomy	Limited duty 3 months after injury
5.	11 February, 1945	28	1.5 hours	Sympathectomy immediately following ligation of artery	1000 cc. blood transfusion during operation. 500 cc. blood transfusion, 16 February, 1945	38%, 15 February, 1945	Patient walked 2.5 miles at moderate speed, 1 month after injury, with no cramping in the extremity			Limited duty 6 weeks after injury

All cases having sympathectomy showed a decided improvement in the blood supply of the involved extremity.

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# BRIEF COMMUNICATIONS

## FIBROSARCOMA PROTUBERANS

ARISING ON AN OLD BURN SCAR

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THE FOLLOWING CASE is reported because fibrosarcoma protuberans is not a common condition arising on an old burn scar. This condition is called dermatofibrosarcoma, of Darier, or dermatofibrosarcoma protuberans, by Hoffman. It is interesting to note that the original lesion was a dermatofibroma which eventuated into fibrosarcoma.

**Case Report.**—W. H., a painter, age 48, married, white, was referred by me to University Hospital, November 16, 1944, complaining of generalized weakness, loss of weight, and a mass on the left chest wall.

**Present History:** About two years previous, patient noticed a smooth marble-sized mass in the left lower chest about three inches below the nipple. At first this was tender on palpation, and was covered with normal skin. This was treated by his local physician with ointments. The tumor gradually grew and finally ulcerated. During the last four months the mass has grown rather rapidly, and has become purulent.

**Past History:** Negative except in the last year patient has developed a rather persistent cough with loss of weight. When the patient was six years of age, his clothes became ignited and he was severely burned over the lower part of the face, neck, left chest and left arm. He was hospitalized for six months, and thereafter was confined in and out of bed for six years because the area did not heal. At age 13 he was operated upon for adhesions between his left chest wall and arm. This apparently was not successful. For the past seven months, the patient has been unable to work as a painter because of generalized weakness and injury to the mass while working.

**Physical Examination:** The patient was a thin, small man, appearing much older than his age, with marked scarring of the face, chest, and left arm. There is a large band of adhesions between his left chest wall and arm extending from the axilla midway down his arm. Over the left lower chest wall there is a large, cauliflower, fungating, purulent, ulcerative mass, about four inches in diameter, protruding about three inches (Fig. 1). The mass is rather hard and bleeds very readily upon the slightest disturbance. There are no subjective symptoms. The mass has a foul odor, and is firmly adherent. His temperature ranged between 100°–102° F.

**Roentgenologic Examination:** No evidence of any pulmonary or rib disease.

**Biopsy Report:** The nodule is composed of a mass of neoplastic tissue which consists of spindle-shaped cells with a large, very pleomorphic nuclei which are pale-staining and vesicular, with prominent nuclei. Many giant and bizarrely lobulated nuclei are seen as well as multinucleated giant cells. Mitoses are infrequently seen. **Histologic Diagnosis:** Fibrosarcoma (Fig. 2).

*Laboratory Studies.—Sternal Puncture:* The marrow preparations are very cellular and show the following distributions:

Cellular Distribution	Percentage
Myeloblasts . . . . .	0.6
Premyelocytes . . . . .	1.0
Myelocytes . . . . .	20.2
Metamyelocytes . . . . .	57.6
Mature neutrophils . . . . .	12.0
Eosinophils . . . . .	1.6
Basophils . . . . .	0.4
Lymphocytes . . . . .	3.0
Erythroblasts . . . . .	0.4
Normoblasts . . . . .	3.2
M. E. ratio equals 26:1 (myelogenic-erythrogenic)	



FIG 1.—Showing the large protruding vascular tumor arising from scarred tissue of the left chest wall. Note the adhesions between inner arm and chest wall.

## FIBROSARCOMA PROTUBERANS

This represents a very marked myeloid hyperplasia. Numerous counts revealed a picture similar to one below:

### Blood Count

Hb. 11 Gm. per 100 cc. equals	71.5%
Erythrocytes .....	3,730,000
Leukocytes .....	49,500
Polys .....	93%
Lymphs .....	4%
Monocytes .....	2%
Myelocytes .....	1%
Color index .....	.93

Actual Count	
Filament .....	45
Nonfilament ....	48
	46,035
	1,980
	990
	495

The blood and bone marrow picture are consistent with a leukemoid reaction, such as one may see in malignancy.

Serum protein, 6.4. Blood serology, negative. Urinalysis, negative.

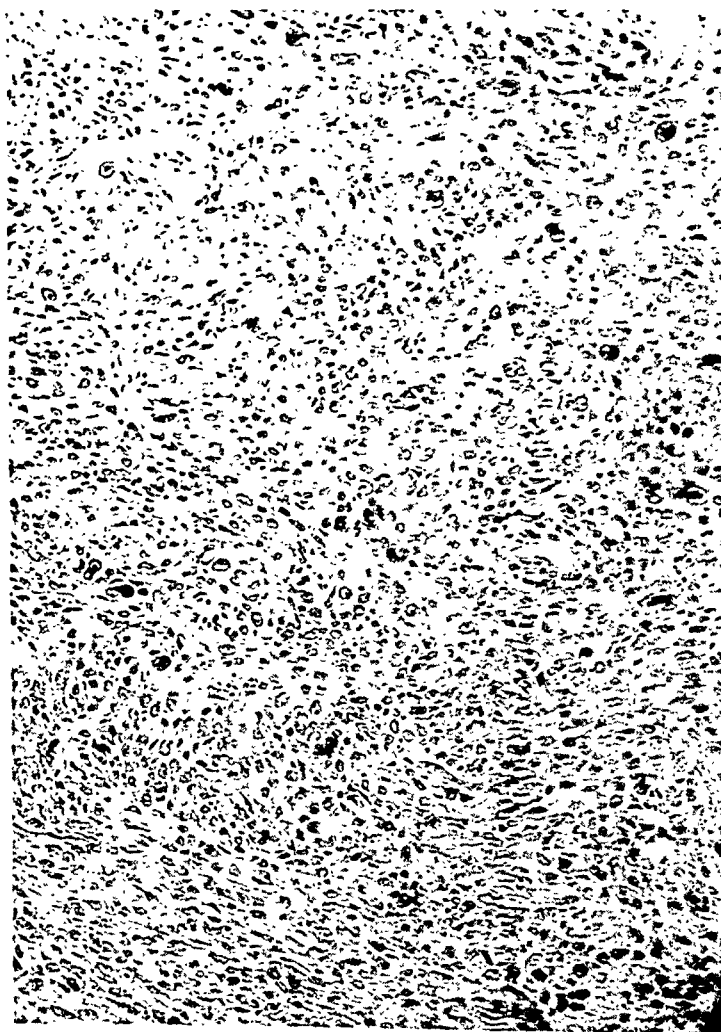


FIG. 2.—Section showing spindle-shaped cells with very large pleomorphic nuclei. Many giant and bizarrely lobulated nuclei are seen as well as multinucleated giant cells.

*Surgical Opinion:* The surgeon was of the opinion that he had nothing to offer this patient in the form of radiation therapy, either by roentgen ray, radium or radon. The diagnosis of fibrosarcoma contraindicated radiation



therapy, as the spindle type of cell is usually very resistant to irradiation. This, coupled with the fact that the patient had an extensive burn scar, and that this tumor had arisen in this type of tissue, contraindicates roentgenotherapy. The extensive ulceration and infection involving the tumor has left no normal tissue, and any treatment given to this area would only help to further necrosis and sloughing. Surgery, likewise, has little to offer, inasmuch as it would necessitate wide surgical resection, possibly even removal of some ribs followed by extensive plastic procedures, from which the patient may never recover.

Senear, Andrew and Willis<sup>1</sup> reported two cases with no metastasis and Geschickter<sup>2</sup> stated that these tumors are not radiosensitive.

#### COMMENT AND CONCLUSIONS

Although dermatofibrosarcoma is not a common condition, it is unusual in that it developed on an old burn scar. In most of the cases reported,<sup>3</sup> no metastasis has occurred, and the condition was cured after complete surgical removal. The microscopic picture is that of a spindle cell sarcoma intermingled among fibrous connective tissue. This condition is usually asymptomatic, and the general health is very little affected.

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#### ANNALS OF SURGERY

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# INTESTINAL OBSTRUCTION DUE TO PERSISTENCE OF THE OMPHALOMESENTERIC ARTERY

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THE PERSISTENCE of the omphalomesenteric vessels in man is a rare congenital anomaly similar in nature to the persistence of a Meckel's diverticulum. Indeed, the two may be associated. There is no doubt that Meckel's diverticula are seen much more frequently than are vascular remains, as shown by the multitudinous reports of cases in the literature on the former. In spite of their rarity in man, Allen<sup>1</sup> has shown that such vessels are very frequently found in new-born cats, dogs and guinea-pigs. The embryology and usual fate of these fetal structures should be reviewed before their nature can be analyzed.

## EMBRYOLOGY<sup>2, 3; 4; 5</sup>

*Meckel's Diverticulum.*—The yolk sac, an extracoelomic structure formed to nourish the developing embryo, is connected to the digestive tract of the fetus by an elongated, narrow stalk which is variously termed the yolk stalk, vitelline duct or omphalomesenteric duct. The latter is incorporated in the umbilical cord and is accompanied by the omphalomesenteric artery and vein which lead to and from the yolk sac. The yolk sac normally loses its connection with the intestine in the embryo of 7 mm. (six weeks), and the omphalomesenteric duct soon degenerates. The time that this occurs is variable and the sac may be present even in an embryo of 12.5 mm. As a rule, the vessels persist for a slightly longer period after the duct has disappeared.

Anomalous persistence of the duct is referred to as a Meckel's diverticulum. A diverticulum of this type usually takes one of several forms. It may establish a fistulous tract from the terminal ileum to the umbilicus or it may persist as a blind sacculation from the intestine. The out-pouching is usually free at its distal end, but it may be anchored by a fibrous cord or by vessels to the umbilicus.

*Omphalomesenteric Artery.*—The aorta in the embryo sends, primitively, the paired omphalomesenteric arteries to the yolk sac. These pass through the mesentery of the intestine, one on each side of the intestine, to the yolk sac. The paired arteries fuse in those portions that course through the mesentery and coelomic cavity. The mesenteric segment of the vessel is destined to become the future superior mesenteric artery. Usually, the left limb of that part encircling the bowel disappears and a single omphalomesenteric artery which passes entirely on the right side of the intestine remains (Fig. 1). Normally at about the sixth week of intra-uterine life that portion of artery between intestine and umbilicus disappears.

Persistence of the omphalomesenteric artery in man is seen only occasionally. When present it may coexist with a Meckel's diverticulum or may be found either alone as a free cord (being attached only at one end) or uniting the mesentery of the terminal ileum to the anterior abdominal wall, usually in the vicinity of the navel. Whether the right or left limb of the early arterial ring has persisted, will determine on which side of the intestine the vessel will course. If the left limb remains, the artery will course to the left side of the intestine.

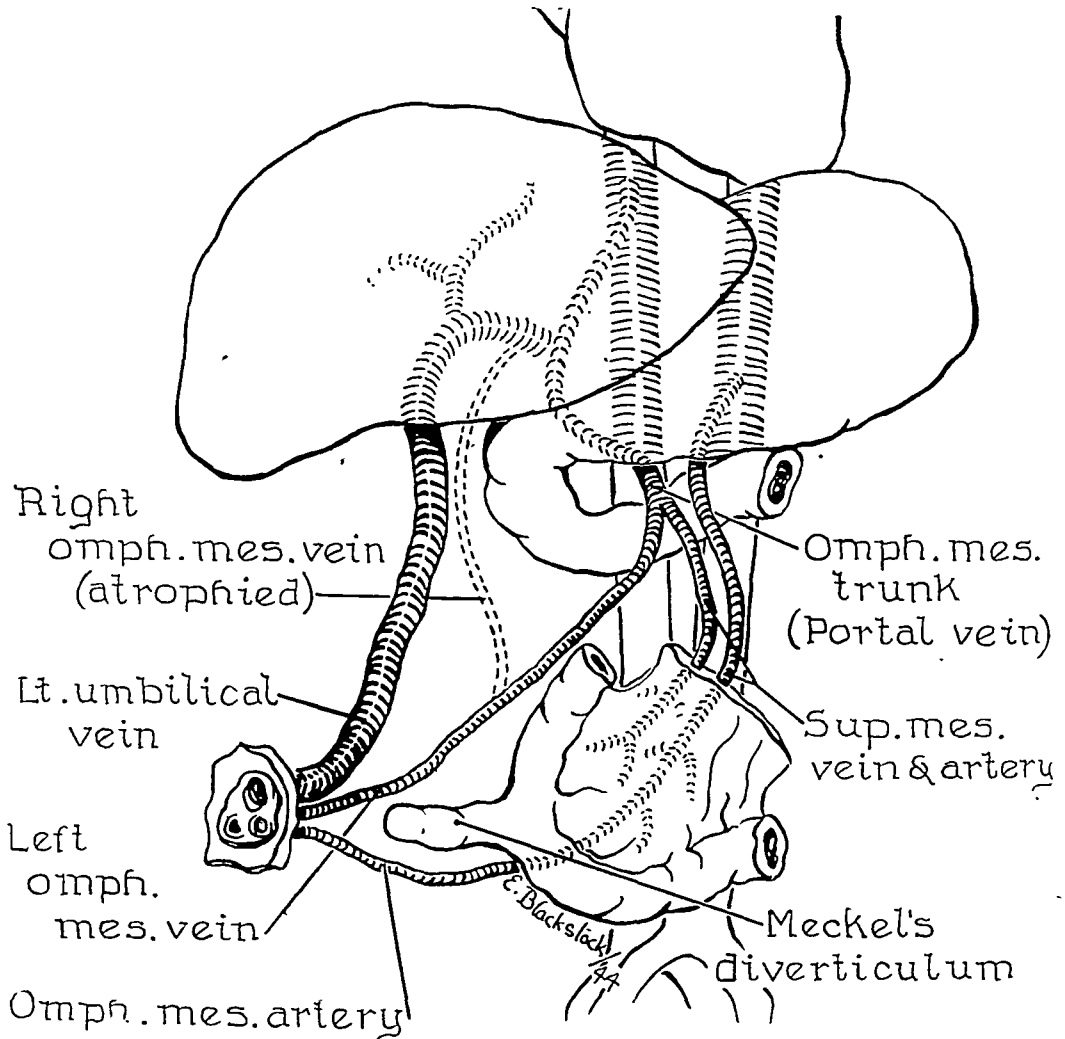


FIG. 1.—Embryologic structures in the region of the umbilicus.

*Omphalomesenteric Vein.*—The omphalomesenteric veins are paired, arise from the yolk sac, and empty into the right and left horns of the sinus venosus of the primitive heart. The veins in their course into the sinus venosus are interrupted by growth of the liver bud, and very soon the left vein is broken up to form liver sinusoids. These still drain into the left horn of the sinus venosus. At this time the left umbilical vein anastomoses with the liver sinusoids, and the right umbilical vein atrophies. Three anastomotic channels are next formed between the omphalomesenteric

veins before their entrance into the liver. These are in the region of the intestine which is destined to become duodenum and which they encircle. Certain of these anastomotic channels along with the right omphalomesenteric vein atrophy and disappear and a common S-shaped omphalomesenteric trunk reaches the liver. The trunk receives the superior mesenteric vein at the level of the middle anastomotic channel, and from this point to the liver the trunk later forms the portal vein (Fig. 1). Normally the portion of the vein from the umbilicus to the duodenum (in the region of the head of the pancreas) vanishes at about the sixth week of embryonic life. When this vessel persists, it is usually present in a similar fashion as is the omphalomesenteric artery. It may be present either alone, as a band, or in conjunction with a Meckel's diverticulum.

**Case Report.**—The patient, a 38-year-old male, was admitted to Dr. W. E. Gallie's service, with acute small bowel obstruction. Four days before admission there was a sudden onset of crampy abdominal pain which was followed within an hour by vomiting. The pain became progressively more severe. Emesis continued with increasing frequency, and later the vomitus became fecal. There were no bowel movements during this period.

A similar attack of abdominal pain had occurred two weeks prior to admission and at various intervals during the last two years.

Physical examination revealed marked abdominal distention. No localized abdominal tenderness was elicited and no masses were palpable. A slight amount of free fluid was present in both flanks. Surgery was contemplated after a course of preoperative preparation (Miller-Abbott tube and intravenous fluids), but the patient began to have respiratory distress due to atelectasis of the right lung. He died 12 hours after admission.

**Necropsy.**—A firm, round, tapering cord covered by peritoneum, extended from the umbilicus to the mesentery of the small bowel. The cord was 6 cm. in length, passed to the right of the bowel, and was inserted in the mesentery 3 cm. away from the attached border of the ileum and 20 cm. proximal to the ileocecal junction. No gross vascular communications at either end of the cord were found. The umbilical end of the cord was of greater thickness, measuring 8 mm. in diameter, whereas, the mesenteric end measured 4 mm. The small bowel had looped itself about the cord and was enormously distended and discolored but still viable. Two hundred cubic centimeters of fluid were found in the flanks and pelvis. No other developmental abdominal defect was present.

The bronchi contained mucous plugs, and atelectasis of both lungs (more marked on the right) was found. The remaining viscera showed no abnormalities.

**Histologic Examination:** Cross-sections of the band through the umbilical and mesenteric ends and through the midportion were examined. The center in all sections was occupied by a thick-walled muscular artery having an internal and an external elastic lamina (Fig. 2). Red blood cells were present in the lumen. The artery was immediately surrounded by a fibromuscular zone of connective tissue which was rich in coarse elastic fibrils and which contained several nerve fibers. The remainder of the band was made up of fat and loose areolar connective tissue. This was most pronounced through the umbilical portion and accounted for the greater thickness of the cord in that area. The outer surface of the cord was covered by peritoneum.

No vestigial intestinal or venous remnants were found in the sections.

**DISCUSSION.**—Meckel<sup>6</sup> contributed much to the present subject. He

established the fact that the vascular remnants are due to embryologic mal-development rather than to a postinflammatory reaction. Fitz,<sup>7</sup> in a comprehensive paper on "persistent omphalomesenteric remains" in which he reviewed the embryology of the umbilical region, furnished strong confirmation of Meckel's views.

Of the vascular remnants the artery persists more frequently, since only two cases of a persistent omphalomesenteric vein have been encountered in the literature. One of the cases in which the vein was patent and connected the navel with the superior mesenteric vein was reported by Spangenberg.<sup>8</sup>



FIG. 2.—Cross-section of the umbilical band. (Weigert's elastic tissue stain,  $\times 75$ )

The other was presented by Buchanan and Wapshaw.<sup>9</sup> The course of the band in the latter case coincided with that taken by the omphalomesenteric vein, *i.e.*, originating at the umbilicus, proceeding upward on the surface of the mesentery of the small bowel, and ending retroperitoneally in the region of the third part of the duodenum. Histologically, the band contained three thick-walled veins in addition to fat and areolar connective tissue.

The relationship of a persistent omphalomesenteric artery to the abdominal viscera varies widely but usually falls into one of three groups as listed below:

1. The most common persistence is in the form of a band or cord extending from the anterior abdominal wall in the region of the umbilicus to the mesentery of the small bowel a short distance proximal to the ileocecal valve. This was true in our case, and was also shown in the case reported by Mahomed,<sup>10</sup> in which the vessel took origin from the anterior abdominal wall midway between the umbilicus and pubis, was inserted into the mesentery of the ileum about three feet from the ileocecal valve, and terminated in a large branch of the ileocolic artery.

2. It may be found as a band in association with a Meckel's diverticulum.

A good example of this can be seen in a case reported by King,<sup>11</sup> in 1843, in which a Meckel's diverticulum was adherent to the umbilicus, forming a fecal fistula, and in which an "adventitious cord" was found passing from the mesentery to the midpoint of the diverticulum. The band had compressed the ileum just distal to the intestinal attachment of the diverticulum. This cord was presumed to be a persistent artery. Another variant of this anomalous coexistence is offered in the case report of Derbes and Hoge.<sup>12</sup> In their case, the omphalomesenteric artery accompanied the diverticulum which was attached to the navel by a fibromuscular structure. The latter was thought to be the obliterated portion of the diverticulum. The arterial remnant communicated at the navel with the inferior epigastric and with the obliterated hypogastric arteries and at the mesenteric end with an ileal branch of the superior mesenteric artery.

3. The least common form of persistence is that of a cord attached only at one end. The attachment may be either at the umbilicus or on the mesentery. The free end is usually rounded and is seen floating in the abdominal cavity. Ruge<sup>13</sup> and Gautier<sup>14</sup> have observed such findings.

Persistence of the omphalomesenteric artery is a constant menace because of the complications that it may produce. At times, however, it is found incidentally, apparently causing no symptoms. Tuberculosis was the cause of death in the case of a dissecting room cadaver, reported by Derbes and Hoge.<sup>12</sup> The hospital record contained no history referable to the abdomen or gastro-intestinal tract. An apparently symptomless persistent omphalomesenteric artery was found by Gisel<sup>15</sup> in a new-born child dying of an intracranial hemorrhage.

Mild symptoms are sometimes produced, as illustrated in a report by Shaw<sup>16</sup> who had performed an hysterectomy for vaginal bleeding and incidentally found a band, which proved to be an anomalous artery, stretching from the mesentery of the ileum to the anterior abdominal wall in the region of the right inguinal ring. This had transfixed the omentum in the right lower quadrant and apparently had caused a chronic aching pain in the right iliac region.

The commonest complication of a persistent omphalomesenteric artery is intestinal obstruction. This may be due either to looping of the bowel about the cord, as was the event in the present case, or to herniation of the bowel through a loop, as in one of the cases cited by Fitz,<sup>7</sup> from the Warren Museum. The obstruction may be due to kinking alone, as was illustrated by King.<sup>11</sup>

Intra-abdominal hemorrhage from a persistent vessel is indeed a rare complication. Fraser and McCartney<sup>17</sup> reported a case in which this finding was present 48 hours following cauterization of the umbilicus for "granulation tissue." The vessel had ruptured at the mesenteric attachment causing the formation of an hematoma which, in turn, had ruptured into the peritoneal cavity.

The case under consideration is of interest for several reasons. On account of the history of several attacks of abdominal pain, one must assume

that looping of the intestine about the vessel had occurred at various intervals. Unwinding of the involved loops of bowel was spontaneous until the last attack. In view of several such abdominal catastrophes, with impending to full-blown intestinal obstruction, in the absence of visible herniae, a persistent omphalomesenteric vessel must be considered in addition to the other causal factors.

At autopsy, even though no gross communication of the persistent artery with other vessels could be found, there is no doubt that such a connection had existed, since red blood cells were present microscopically in the lumen of the vessel. It is evident that during embryonic development it was the right limb of the artery that persisted, since the vascular remnant imbedded itself in the mesentery of the ileum to the right of the intestine.

#### SUMMARY

A case of intestinal obstruction due to a persistent omphalomesenteric artery is presented, together with a review of the embryology of the umbilical region. Obstruction is the most frequent complication of this anomaly, intra-abdominal hemorrhage being much more rare.

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## BATTLE WOUNDS OF THE THORACIC CAVITY

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DURING THE RECENT CAMPAIGN in North Burma there was an unusual opportunity to observe and treat wounds of the thoracic cavity. There were 308 patients with such wounds admitted to the 20th General Hospital during the period from December, 1943, to March, 1945. Six of the wounds were due to bayonets, 153 to bullets and 149 to shell, mortar, grenade, bomb or mine fragments. The high percentage of bullet wounds was due to the fact that this campaign was carried on under conditions which made it largely small arms warfare. There were 240 Chinese, 59 Americans, three Japanese, two Gurkas, two Kachins, one Indian and one Englishman. More than 50 per cent of the patients were received within 36 hours of the time of wounding, while 10 per cent were received within 12 hours. The patients were sent to this hospital as rapidly as their conditions and the circumstances of the campaign permitted. A few patients were received from other fixed hospitals more than three weeks after injury. These obviously represented the residue of a much larger group of patients treated in those hospitals and are not included in this series. It is believed, therefore, that this series of patients is an unselected group of battle wounds of the thoracic cavity. In addition to receiving the patients relatively early, with only a few exceptions we were able to care for and observe them until their wounds had completely healed. In this respect the opportunity was unusual.

Ninety per cent of the patients had been operated upon in the portable surgical hospitals. These hospitals were set up in the jungle as close as possible to the Japanese line, with the minimum of equipment since their supplies were carried on horseback or dropped by parachute. The casualties received sulfonamides locally and by mouth from the first-aid men and reached the portable surgical hospitals from one to eight hours after being wounded. The administration of sulfadiazine by mouth was continued during the entire evacuation. The good results obtained in this series of patients are to no small degree a tribute to the men who worked in those forward echelons.

By and large the surgery undertaken was conservative. The wounds were simply débrided and closed, with little effort to explore the pleural cavity. If sucking could be controlled by suturing the muscles only, the skin was left open. In a few instances there were large open wounds so that the lung was exposed. In these cases the wound in the lung was sutured, the opening in the chest wall closed by a muscle flap if necessary and the lung reexpanded by thoracentesis. In some instances the skin was also sutured to insure an



air-tight closure. The patients were evacuated to this hospital by air, usually on the following day, but occasionally on the same day.

When the patients arrived in this hospital they were seen immediately, and an effort made to evaluate the severity of their condition. A note usually accompanied the patient describing the operative procedure which had been done in the forward area. We soon got to know the surgeons in the portable surgical hospitals by their work, if not personally. Under such circumstances if the patient had what was expected to be a clean wound and if he showed no evidence of infection, the original dressing was not removed for four or five days. When no note accompanied the patient, or if he had been operated upon by a surgeon with whose work we were not familiar, it was our practice to inspect the wound immediately. During the latter part of the campaign all wounds have been subjected to early secondary suture which greatly reduced the time required for convalescence.

Many of the patients required emergency treatment upon admission to this hospital in spite of excellent early care. This was due to (1) blood loss and shock; (2) a disturbance of the mechanism of respiration; or (3) a combination of these two.

#### EMERGENCY TREATMENT

1. *Blood Loss and Shock*: When the patient presented a shock-like picture but was found to be aerating his lungs adequately he was treated by the transfusion of whole blood.

2. *Mechanical Disturbance of Respiration*: When the patient was dyspneic it was due to either, or both, of two causes.

a. *Pneumohemothorax*: Reduction of breathing space by pneumohemothorax, with deviation of the mediastinum to the opposite side was treated by immediate thoracentesis for relief of the dyspnea.

b. *Tracheobronchial Obstruction*: When there was an intrapulmonary injury with bleeding or excessive pulmonary secretions obstructing the tracheobronchial tree, with patchy or massive atelectasis, constant care was required to encourage the patient to cough and clear the tracheobronchial tree of secretion. Aspiration with a tracheal catheter was occasionally necessary.

c. *Hemorrhage, Shock, Hemopneumothorax and Tracheobronchial Obstruction*: The sickest patients were those in shock from trauma and blood loss who had severe pulmonary injury with partial obstruction of the tracheobronchial tree by blood and mucus, and whose lung volume was further reduced by an hemopneumothorax. Such patients were given whole blood, subjected to thoracentesis, and encouraged to cough to clear the tracheobronchial tree. Tracheal aspiration was used when necessary.

Only a few patients, however, were still coughing up fresh blood upon admission, but a large number were coughing up old blood and continued to do so for several days. In the patients who needed blood or fluids because of shock or dehydration or both, there was always some hesitation in building

up their blood volume too suddenly for fear of precipitating fresh pulmonary bleeding. This, however, occurred in only one instance, and that was in a patient who inadvertently received 2,000 cc. of fluid in about 45 minutes only 24 hours after being wounded.

In the patients who were dyspneic due to hemopneumothorax, we were fearful that thoracentesis, with early reëxpansion of the lung might precipitate fresh pulmonary hemorrhage. In no instance, however, did this occur. It should be stated that seldom was over 750 to 1,000 cc. of air or blood removed at a single thoracentesis.

#### HEMOPNEUMOTHORAX

It is agreed by all that if a patient is dyspneic due to the pressure of an hemopneumothorax, thoracentesis should be done immediately to relieve the dyspnea. However, there is some difference of opinion as to the management when dyspnea is not a factor. It was my opinion in civilian practice that there was seldom justification for allowing a massive hemothorax to go untreated, or even for the replacement of the blood by air. The experience with the present group of battle wounds has tended to strengthen that opinion.

Although a few patients have been allowed to absorb large hemothoraces spontaneously, as a rule the blood and air have been removed by one or more thoracenteses as early as seemed reasonable. When dyspnea was not present the first thoracentesis was usually done three to five days after the patient was wounded. About 750 to 1,000 cc. of blood and air were removed at the first aspiration, and this was repeated every day or two until the lung was reëxpanded as completely as possible (Fig. 1). There were 140 patients with sufficiently large hemothoraces or hemopneumothoraces to be diagnosed. Of this group, 103 were subjected to one or more thoracenteses. When the hemothorax was very small it was left alone.

A small number of large hemothoraces were allowed to go untreated. Although the blood was absorbed in all but three cases, two definite impressions were gained. First, the patients had to stay in the hospital longer because of the time required to absorb the hemothorax; and, second, the patients were left with more deformity in the form of a thickened pleura and as a result a partially fixed hemothorax. An additional disadvantage of allowing a massive hemothorax to go untreated or to replacing the blood by air, was the size of the empyema when infection did occur. When infection occurred after the lung had been rapidly reëxpanded by repeated thoracenteses, the empyema was much smaller and responded more rapidly to treatment.

There are only two possible disadvantages to early reëxpansion of the lung by thoracentesis. First, there is the possibility of starting fresh pulmonary bleeding as the lung reëxpands. This did not occur in a single instance in this series in sufficient degree to be diagnosed. The only patient who bled had not had a thoracentesis. It cannot be said dogmatically that no intrapleural bleeding was precipitated, but if so, it was not demonstrable. Second, there is the possibility of introducing infection into the hemothorax. There is no reason to believe that such occurred in any of these patients.

There were 30 patients who developed empyema, an incidence of 9.7 per cent. Of these 30, only seven had negative cultures at their original thoracentesis, and in these the source of the subsequent infection appeared obvious.

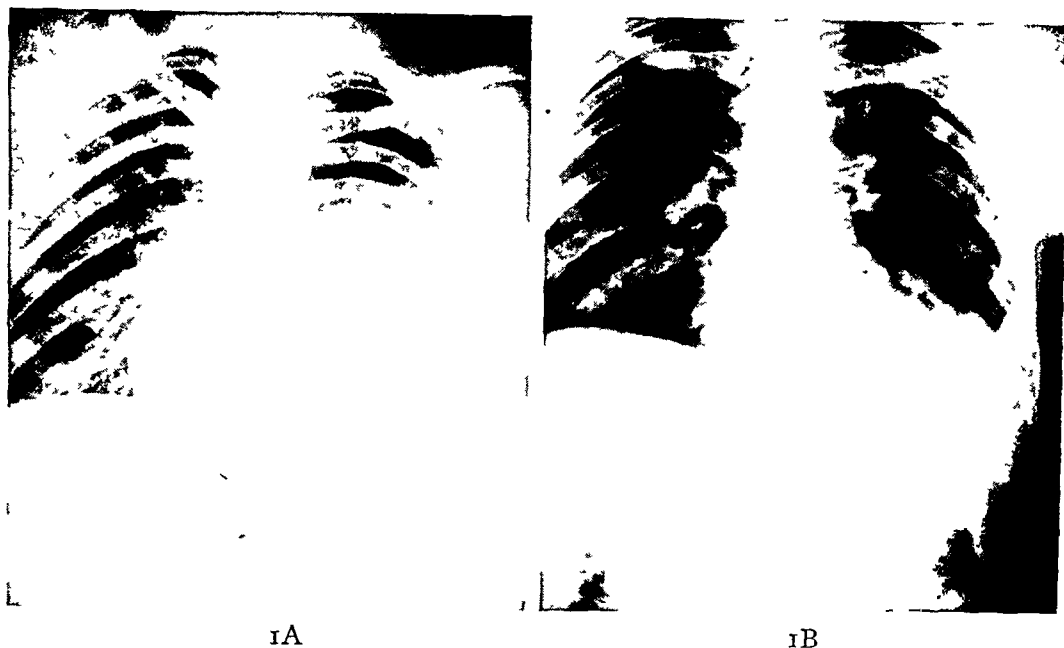


FIG. 1.—(A) An hemopneumothorax from a perforating 25-caliber rifle bullet wound, five days after injury.

(B) Three days later, after two thoracenteses, the lung was completely reexpanded and breath sounds came through normally except at the extreme base. The fluid did not reaccumulate. Such a procedure makes early return to duty possible with no disability.

Every patient who developed an empyema had high fever at the time he was admitted to the hospital and continued to have it until the empyema was drained. A number of the patients with hemothorax had considerable fever for some time without developing empyema, but this was the exception rather than the rule. In only ten instances did patients with hemothoraces maintain a fever of  $101^{\circ}$  F., or over, for more than two weeks without going on to suppuration, and only one patient had such a fever for over three weeks, to have it subside uneventfully. It is probable that the febrile course was due to infection in the lung rather than to uninfected blood in the pleural cavity for many of the patients with hemothoraces had little or no fever. In no instance did a patient with little or no fever on admission develop an empyema after thoracentesis. All these factors together lead one to discount the probability of introducing infection into the pleura by thoracentesis.

#### CLOTTED HEMOTHORAX

Unfortunately, it was not always possible to reexpand the lung by thoracentesis when an hemothorax was present. In 11 instances, or 8 per cent of the 140 patients with hemothorax, the blood appeared to have clotted and could not be aspirated satisfactorily. A small amount of clotting very probably occurred in many of the hemothoraces, but only in these 11 was it sufficiently extensive to become a real problem.

Perhaps three of these should not properly be said to have had a clotted hemothorax, but they presented the same problem. They started primarily as pneumothoraces with very little blood. In each instance there was a temporary bronchopleural fistula with infection of the pleural cavity. Serum poured out into the pleural cavity and clotted to form multiple cystic collections which did not communicate freely. They presented multiple fluid levels upon roentgenologic examination (Fig. 2). At operation, these looked just

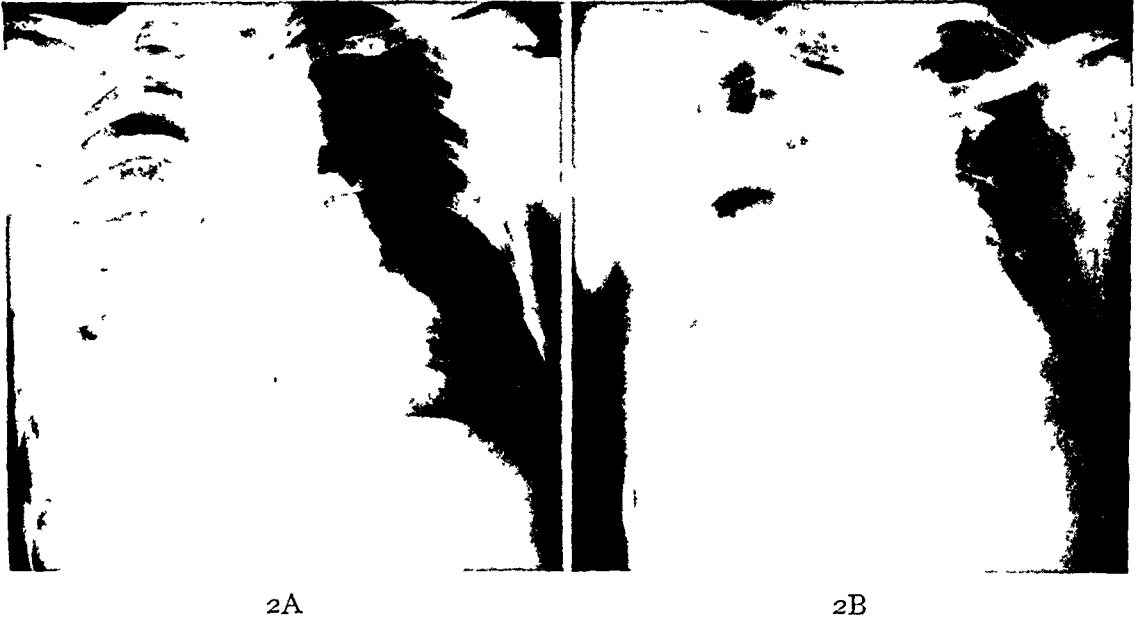


FIG. 2.—(A and B) shows two different patients with clotted hemothoraces. Both started primarily with a pneumothorax. Serum poured out into the infected pleural cavity to clot and produce the multiple fluid levels demonstrated. Both had open drainage with complete removal of the blood clot. A suction of about 150 cm. of water was applied. Both attained complete reëxpansion of the lungs, with obliteration of the empyema cavity. Both returned to duty.

like the infected serum pocket seen following a total pneumonectomy without drainage.

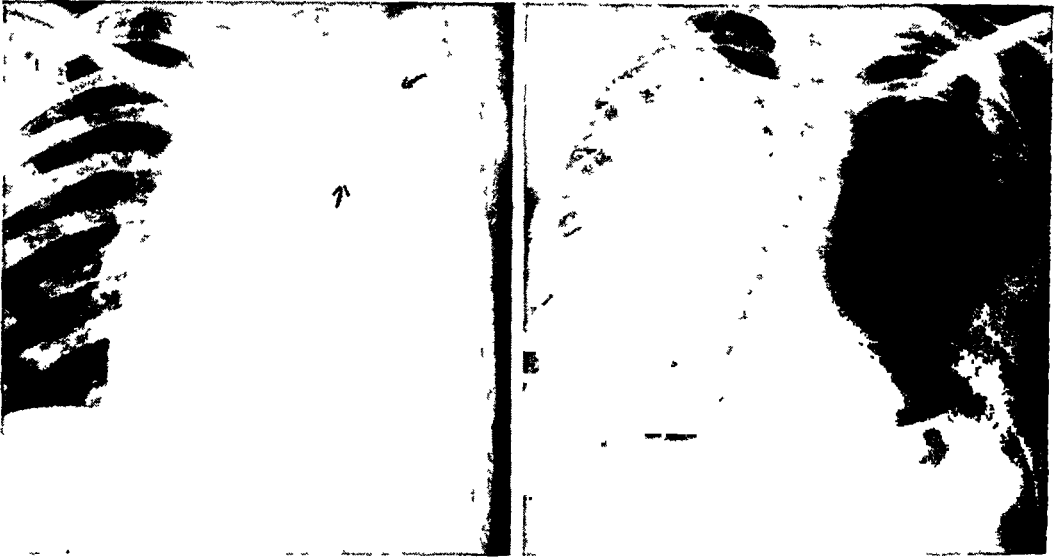
The remaining eight patients had clotting in massive hemothoraces. Here, again, there were multiple cystic collections some of which apparently communicated, while others did not. One could get a small amount of fluid by aspiration almost anywhere in the chest, but when one cystic collection had been emptied the needle had to be moved before additional fluid could be obtained. When air was present, multiple fluid levels were found upon roentgenologic examination (Fig. 3), when no air was present simply a massive density to roentgen ray was found.

Eight of the 11 patients had infection. They will be discussed under the section on empyema. Two of the remaining three patients were treated conservatively early in the campaign; one absorbed his blood to a large degree, but was left with a very much thickened pleura and a partially fixed hemothorax. The other had not absorbed his hemothorax when sent to the Zone of Interior. The third patient was received late in the campaign and was subjected to open thoracostomy, with evacuation of the blood clot and decorti-

cation of the lung as practiced in the Mediterranean Theater.<sup>1</sup> Certainly this appears to be the treatment of choice.

### TENSION PNEUMOTHORAX

A patient with tension pneumothorax requires immediate treatment. Rapidly recurring tension pneumothorax fortunately was not common. There were 50 patients who had sufficient shift of the mediastinal structures to be diagnosed upon clinical examination. Unless the tension pneumothorax recurred rapidly it was treated by repeated thoracenteses. In most instances after two or three days the wound in the lung sealed and the pneumothorax no longer recurred. When the tension pneumothorax was sufficiently severe, there was no hesitancy in introducing a catheter between two ribs into the



3A

3B

FIG. 3.—(A) Shows a clotted hemothorax with two fluid levels. The patient ran a high fever and the culture of his original thoracentesis was positive.

(B) Open thoracostomy was not undertaken until almost six weeks after injury. The cavity measured more than 1,200 cc. This picture was taken after 17 days of continuous suction of about 150 cm. of water reduced the cavity to 50 cc. Suction was maintained until the cavity was only 5 cc. The wound healed rapidly thereafter.

pleura and sealing it under water. After four or five days, when it seemed likely that healing was underway, suction of 10 cm. negative pressure (water) was applied. This allowed for complete reëxpansion of the lung in a short time. The procedure was used in only four patients, while only one patient was brought to the hospital with a catheter in the pleural cavity. The negative pressure was maintained for about two weeks and then the catheter slowly removed to insure that the pleural space was obliterated and that the pneumothorax did not recur. Only one of these patients developed infection, and that was in the lung rather than the pleural cavity. The early reëxpansion of the lung by this method would tend to minimize the extent of the infection in the pleura, should it occur.

In only two patients did the bronchopleural fistula remain open for more than a week, thereby preventing reëxpansion of the lung by thoracentesis.

without developing an empyema. Neither of these had a tension pneumothorax. One of them did not seal his bronchopleural fistula until one month after injury, at which time his lung could be reexpanded by thoracentesis.

#### SUBCUTANEOUS EMPHYSEMA

Physical examination revealed subcutaneous emphysema in 29 patients. In only two was it present to a startling degree. In both, it extended from above the eyes and ears to the back of the fingers and to the scrotum, which was blown up like a balloon. There was about two inches of air under the skin of the abdomen and thorax. The eyes were completely closed but could be temporarily opened by pressing air away from this area. The air did not extend below the upper thighs. In both instances there was a tension pneumothorax so that a catheter was introduced between two ribs within a short time after admission to the hospital. The relief of the tension pneumothorax prevented extension of the emphysema very nicely in one patient and the major part of the air was absorbed from the subcutaneous tissues in about ten days.

In the other patient the subcutaneous emphysema decreased at times, but returned with coughing. Examination showed that the bullet had perforated the trachea low in the neck before traversing the right pleura. It became apparent that as the patient coughed air was forced out of the trachea into the mediastinum and subcutaneous tissue. It seemed likely that tracheotomy would prevent the marked increase in intratracheal pressure which occurred during coughing. Thus, when the trachea was exposed and the wound was found to be situated posteriorly and in a fairly inaccessible location, a simple tracheotomy was performed. This proved to be entirely satisfactory and the subcutaneous emphysema decreased progressively thereafter.

Although there were several patients in this series with some mediastinal emphysema, there was no patient in whom a wound of the mediastinal trachea or bronchus was diagnosed. The treatment usually recommended for a wound of the mediastinal trachea is to open the mediastinum through the neck, dissect down to the hole in the trachea and pack the wound open. When the wound is too low to reach in this manner, a thoracotomy with an attempt to suture the trachea has been recommended. In order for the air to go out of the trachea into the mediastinal tissues, the pressure in the trachea must be greater than that in the mediastinum. It is probable that in most instances this occurs only during coughing, for during coughing an expiratory effort is made against a closed glottis until the intratracheal pressure is very high. Then the glottis suddenly opens. By performing a simple tracheotomy the increase in intratracheal pressure is prevented. In view of the excellent result obtained in this one patient, it seems highly probable that a good proportion of tracheal wounds with mediastinal emphysema could be treated satisfactorily in this manner, using chemotherapy to prevent spreading mediastinal infection.

#### LUNG INJURY

More than half of the patients had little or no hemopneumothorax, as ascertained by physical examination or roentgenology. About 85 per cent of

the patients were examined roentgenologically, the first film being taken as a rule about seven to ten days after injury. The patients with simple lung damage as the result of a rifle bullet or shell fragment were treated conservatively. Usually the density in the lung shown roentgenographically cleared surprisingly rapidly and disappeared completely in three to four weeks.

In a number of instances the course of the bullet or shell fragment could be traced through the lung (Fig. 4). At times the amount of damage as seen by roentgenologic examination was surprisingly small. In three patients roentgenograms showed a healthy chest although a bullet had obviously passed directly through the lung from front to back a week, or less, before the examination.

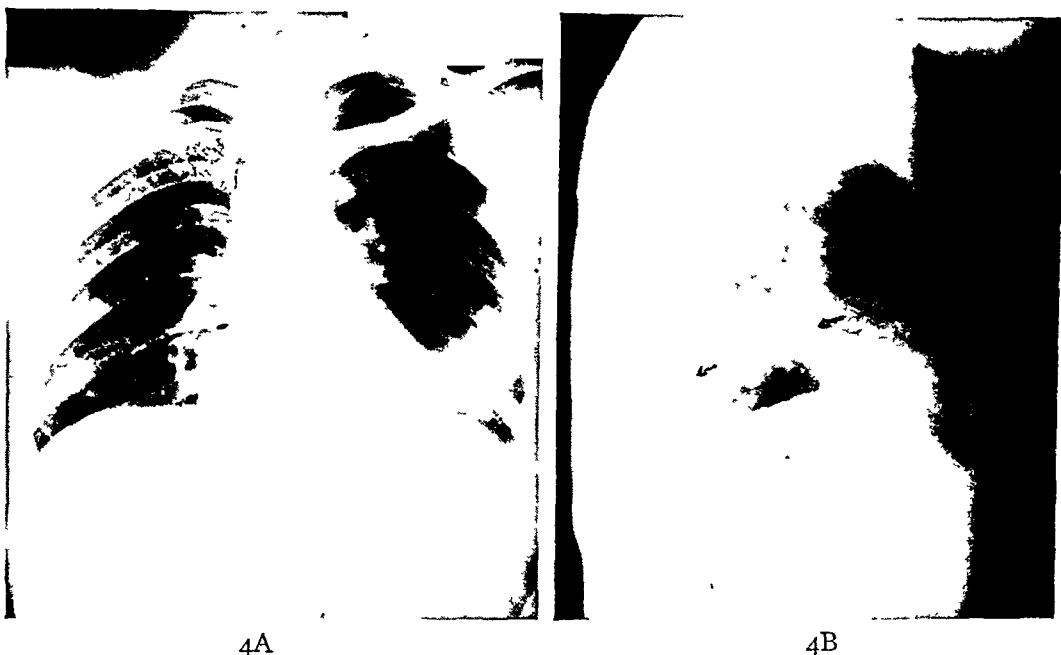


FIG. 4.—A perforating rifle bullet wound of the left lung five days after injury.  
(A) The A.P. view shows minimal changes.  
(B) The course of the bullet through the lung can be seen in the lateral view.

It had been anticipated that as a result of trauma and hemorrhage within the lung, infection followed by a typical lung abscess might develop in some of these patients. This, however, occurred only twice, and both patients died from multiple lung abscesses.

It is probable that the prolonged fever seen in some patients with hemothorax represented simultaneous infection within the lung. Infection within the lung no doubt was relieved or obscured in some instances by drainage into a bronchus or into an empyema cavity. It was not uncommon to observe air pockets (pneumatocoles) within the damaged lung which did not go on to typical abscess formation (Fig. 5). Whatever the incidence of infection within the wound of the lung itself, it became a recognizable major factor in very few instances.

#### EMPHYEMA

*Principles and Methods of Treatment.*—The fundamental objectives in the treatment of empyema are to obtain adequate drainage and to achieve the

reëxpansion of the lung as rapidly as possible. Repeated thoracenteses and closed drainage through a catheter introduced into the pleural cavity are the two methods commonly employed early in the disease. Unfortunately, there is usually sufficient exudate to prevent adequate and complete drainage by either of these methods. On the other hand, early open drainage to remove this exudate allows the lung to collapse and is the procedure which accounted for a considerable part of the mortality from empyema in World War I. For



FIG. 5.—A perforating shell fragment wound of the right lung showing considerable lung damage with cavity formation. The picture was taken eight days after injury. The patient had little or no fever. Healing occurred uneventfully.

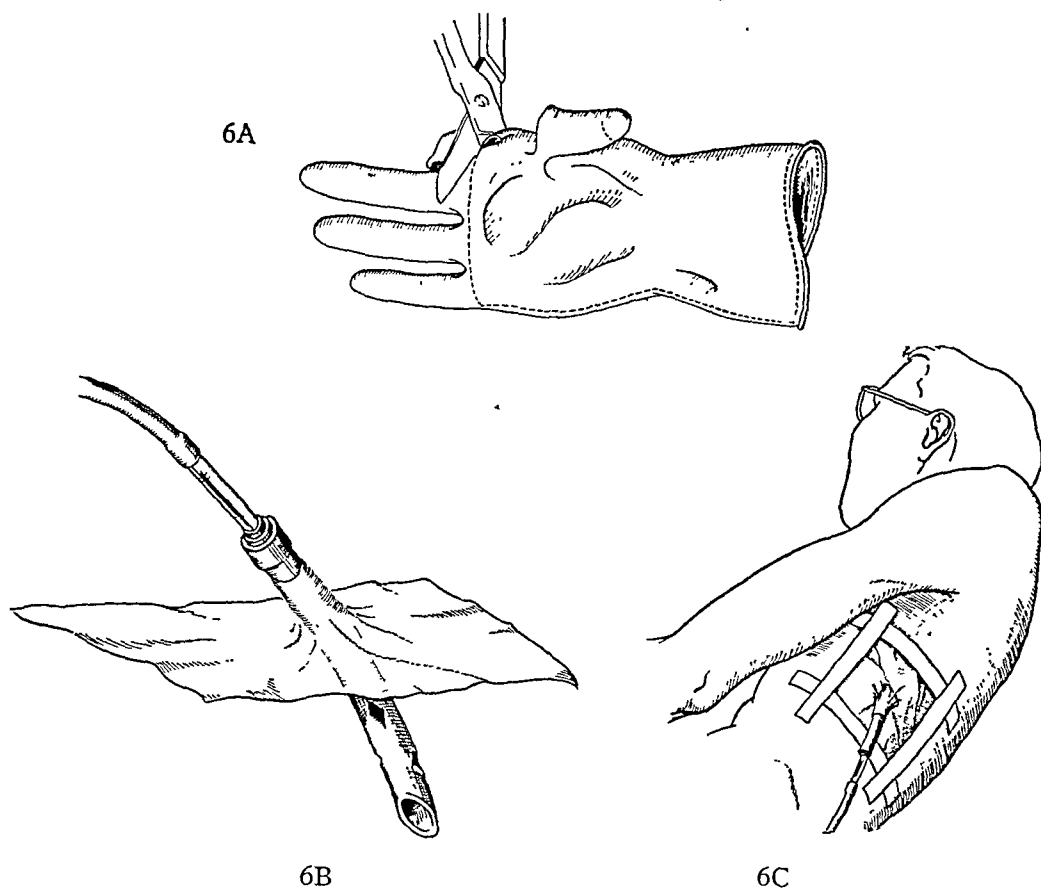
this reason either repeated thoracenteses or closed drainage is usually advocated to reduce the size of the empyema cavity as much as possible until the lung has become adherent and open drainage is a safe procedure.

Closed drainage has the advantage over open drainage in that it exerts a negative pressure and produces a more rapid reëxpansion of the lung. However, the interrib catheter frequently becomes plugged resulting in ineffective drainage. It is highly desirable to use a method by which the exudate can be removed from the empyema cavity and at the same time allow for closed drainage with the use of negative pressure postoperatively. The conversion of an open empyema into a closed one by an air-tight seal so as to rapidly reëxpand the lung by a high degree of negative pressure is certainly not new.



However, a satisfactory method of applying an air-tight seal may not be familiar to all. Such a method was used in this series of patients and was found to be most satisfactory.

Open drainage was done through a large opening by the removal of segments of two ribs and the intervening muscular bundle. This allowed for the complete removal of the exudate. A three-quarter-inch rubber tube,



Method of Applying Suction to an Open Thoracostomy

FIG. 6.—(A) The fingers but not the thumb are cut from a rubber glove. The tip of the thumb is cut away. The glove is then cut along the ulnar aspect. This will then open to form a sheet of rubber tissue with the thumb in the center.

(B) A large rubber tube is then put through the thumb and glued to it. The tube is connected with an ordinary three-bottle Wangensteen suction apparatus.

(C) The skin around the empyema opening is painted with the glue used with the Padgett dermatone for removing skin grafts. A little gauze packing is placed around the tube to absorb any excessive fluid until the rubber tissue is stuck. The rubber tissue is then held moderately taut and placed down smoothly on the skin surface. The tube must already be connected to the suction apparatus so that suction can be applied immediately. This will pull the rubber tissue tightly against the skin surface so that it may become effectively glued. The edges of the rubber tissue are covered with adhesive. When carefully applied this air-tight seal is effective for 10 to 14 days. With the Wangensteen suction apparatus a negative pressure of up to 150 cm. of water can easily be attained.

with several holes in the sides, was used to insure adequate drainage. An air-tight seal was made to the chest wall by the method shown in the accompanying diagram (Fig. 6). This gave a satisfactory closure, which usually held for about two weeks. It was felt that a high degree of negative pressure

was desirable to insure rapid reëxpansion of the lung. The ordinary three-bottle Wangenstein suction apparatus was quite satisfactory for this purpose and gave about 150 cm. of negative pressure (water). When the seal was tight, and the apparatus did not leak, the water in the bottles had to be changed very infrequently. An incidental advantage to this method of treatment was that the frequent dressings usually required by an empyema were avoided.

During the early part of the campaign repeated thoracenteses were employed until the lung had become fixed and the open drainage with the complete removal of the exudate could be done under local anesthesia. It was then converted to closed drainage by the air-tight seal and a high degree of negative pressure applied. This air-tight seal proved to be so satisfactory and reliable that during the latter part of the campaign the open drainage with removal of the exudate was undertaken early (7-14 days), under endotracheal anesthesia. This offered the advantage that the layer of fibrous tissue over the lung was still quite thin, so that the lung could be reëxpanded more rapidly.

Decortication of the lung, as practiced in the Mediterranean Theater, was undertaken only once (the most recent case) in this series of empyemas. By complete removal of the exudate is meant the removal of all the exudate that can be removed by the hand and a sponge. At this point, the lung could not be completely reëxpanded with positive pressure anesthesia, because of the residual layer of fibrous tissue over the lung surface. The subsequent application of an high degree of negative pressure (150 cm. of water) did bring about the complete reëxpansion of the lung unless the empyema was very old. By decortication is meant the removal of the layer of fibrous tissue from the lung surface after removal of the exudate in the pleural cavity. After its removal in the one patient, the lung could be completely inflated by positive pressure from the anesthesia apparatus.

Early thoracostomy with complete removal of the exudate followed by the use of an high degree of negative pressure has been most satisfactory in producing the rapid and complete reëxpansion of the lung. The experience with only one case of decortication in empyema does not allow for a proper evaluation of the procedure, but it would certainly seem to be an additional aid in reducing the residual thickening of the pleura in those cases in which it can be done. Churchill<sup>1</sup> points out that after about six weeks the fibrous layer becomes sufficiently organized so that it can not be removed from the lung. The high degree of negative pressure as used in this series is especially valuable when decortication of the lung is not or cannot be done. Because of the degree of suction, there is usually some blood mixed with the drainage for the first few days. The rapidity of the reëxpansion of the lung depended upon the duration of the empyema before the suction was applied. The temptation to remove the suction when the cavity has been reduced to 20-50 cc. should be avoided. Especially in old empyemata the obliteration of this residual cavity may take considerable time because of the thickness of the pleura at the outset. When the suction was removed too soon, the cavity instead of getting progressively smaller frequently increased in size. It was

found to be best to maintain the suction continuously. The large tube was replaced by a small one and the suction maintained until the cavity measured less than five cubic centimeters.

When, because of the extent of the wound to the lung in an early case, we were fearful of sudden complete reëxpansion of the lung, only about ten centimeters of water negative pressure was applied. This was obtained by the water suction apparatus commonly used following lobectomy or pneumonectomy with drainage.<sup>2</sup> This type of apparatus was also necessary in cases where there was a small bronchopleural fistula, since the water would flow through the Wangenstein apparatus too rapidly.



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7B

FIG. 7.—(A) This film was taken about two months following the original wound. The lung is almost completely collapsed.

(B) In spite of the delay in applying suction, the lung was completely reëxpanded and the empyema cavity was obliterated. There was considerable residual thickening of the pleura.

#### TYPES OF EMPYEMA ENCOUNTERED

There were 30 patients who developed empyema, giving an incidence of 9.7 per cent. Empyema developed in 5 per cent of bullet wounds, 10 per cent of shell fragment wounds, and 66 per cent of bayonet wounds (six patients). The common organisms found were *hemolytic Staphylococcus aureus*, *non-hemolytic Streptococcus*, and *Streptococcus viridans*. The fact that in not a single instance was the *hemolytic Streptococcus* found upon culture would seem to be ample proof of the value of sulfonamides in this series of patients.

We had the unusual experience of obtaining a pure culture of organisms of the *Salmonella* group from the hemothoraces of three patients. They all had considerable fever. Two of these could not be completely aspirated by thoracentesis and came to open drainage. The third could be aspirated almost completely and did not develop an empyema.

Four general types of empyema were encountered in this series. They will be discussed separately.

*Type 1.—Infection in a Simple Hemothorax:* The common type of empyema occurred in the liquid hemothorax which became infected with an organism of relatively low virulence. There were 16 patients with this type of empyema. Early in the course of their disease these patients looked very little different than those with simple hemothorax except that they invariably ran considerable fever. Upon the initial thoracentesis the blood usually looked uninfected but, as noted above, the cultures were positive with few exceptions. During the early part of the campaign especially, these patients were treated by repeated thoracenteses until the lung became adherent and open drainage could be undertaken. When repeated thoracentesis was effective the empyema cavity was small when the patient came to open drainage. However, there was frequently sufficient thick exudate to prevent anywhere near complete aspiration by thoracentesis. During the latter part of the campaign these patients were operated upon early and the exudate evacuated, under endotracheal anesthesia without waiting for fixation of the mediastinum. With the use of an high degree of negative pressure following an air-tight seal rapid reëxpansion of the lung was obtained.

*Type 2.—Infection in a Clotted Hemothorax:* Eight patients with clotted hemothoraces developed infection. In these there was extensive clotting and the development of multiple cystic collections of fluid which did not communicate freely with one another. In five there was at least some communication, for the initial thoracentesis gave a positive culture, and at operation the fluid in all the cystic cavities appeared infected. In the early part of the campaign operation upon the patients was delayed until there was fixation of the mediastinum. In the latter part of the campaign operation was undertaken early (7–14 days), under endotracheal anesthesia. A large opening was made, the clot completely evacuated (decortication was done in the most recent case), and suction applied. Excellent results were obtained in all. The earlier the operation was done, the less was the residual thickening of the pleura. The high degree of suction (150 cm. of water) was especially helpful in the delayed cases. One patient had a cavity containing over 1,200 cc. when suction was applied six weeks after his original injury. After 17 days of continuous suction the cavity contained only 50 cc. (Fig. 3).

The remaining three patients were received early in the campaign. The multiple cystic collections did not communicate. At operation, some appeared infected and others did not. Cultures of the original thoracenteses were negative because the infected pocket was not aspirated. Considerable time was lost in waiting to obtain pus upon aspiration. At operation, when the exudate was removed, it almost appeared as if the lung had been removed. Nevertheless, complete reëxpansion of the lung was obtained by an high degree of suction.

*Type 3.—Putrid Empyema:* Three patients were admitted to the hospital with putrid empyema. They were desperately sick. The gross character of the fluid obtained by thoracentesis left no doubt as to the diagnosis. These patients differed from those of Type 1 chiefly in the virulence of their infection and the urgency of their treatment. They were subjected to emergency

operation six, seven and 11 days after injury. Large shell fragments were removed from two. A three-quarter-inch rubber tube was inserted, fixed with an air-tight seal and suction applied.

*Type 4.—Infected Open Sucking Wounds:* Three patients were admitted to the hospital with infected open sucking wounds. The urgency of their treatment was apparent but complicated by the inability to suture the wound. They were desperately sick due to the disturbance in the mechanism of respiration, in addition to the infection. Two of these patients were treated by inserting the drainage tube directly into the pleural cavity through the sucking wound and fixing it with an air-tight seal. In the third patient the open wound was high on the back so that it was sealed by covering with a sheet of rubber tissue glued to the skin. The suction was applied through a tube inserted in the midaxillary line (Fig. 8).

*Results in Empyema:* There were no deaths in the group of 30 patients with empyema. One never anticipates a death in a localized empyema. However, a considerable part of the mortality from empyema in World War I was due to rapidly spreading infection. It would seem that the routine use of sulfonamides in this series was an important factor in preventing spreading infection and in avoiding any deaths in this group.

Complete reëxpansion of the lung was obtained in all but two patients. Both of these had large hemopneumothoraces and, unfortunately, were treated conservatively. In each instance the initial fever almost completely subsided and the patients were apparently doing satisfactorily. Late in the course of the disease high fever appeared again. Investigation revealed an empyema incident to an old infection in the lung rupturing into the hemothorax. This was demonstrated at operation. When suction was applied after operation, the lung in both patients had been collapsed to a considerable degree for over two months and was covered by a thick layer of fibrous tissue. Nevertheless by the use of a high degree of negative pressure (150 cm. of water) their cavities were reduced to 15 and 50 cc. An unroofing (Schede) operation was successful in closing the remaining cavity in both patients.

#### FOREIGN BODIES IN THE THORACIC CAVITY

In the majority of wounds the missile traversed the thoracic cavity. In only 61 patients (20 per cent of this series) was a foreign body found to be in the thoracic cavity. Although the thoracic wounds were due equally to bullets and shell fragments, in only seven instances did a bullet remain in the thoracic cavity, as compared to 54 shell fragments.

It was of some interest to determine the influence of the retained foreign body upon the course of the wound. The incidence of hemothorax as opposed to simple lung trauma was the same, whether the missile traversed the chest cavity or stopped in it. Neither was there a significant difference in the incidence of empyema.

It had been anticipated that infection would occur in the lung around the retained foreign body and that a typical putrid lung abscess might develop. In no instance was this definitely demonstrated. In a number of patients

## BATTLE WOUNDS OF THORACIC CAVITY

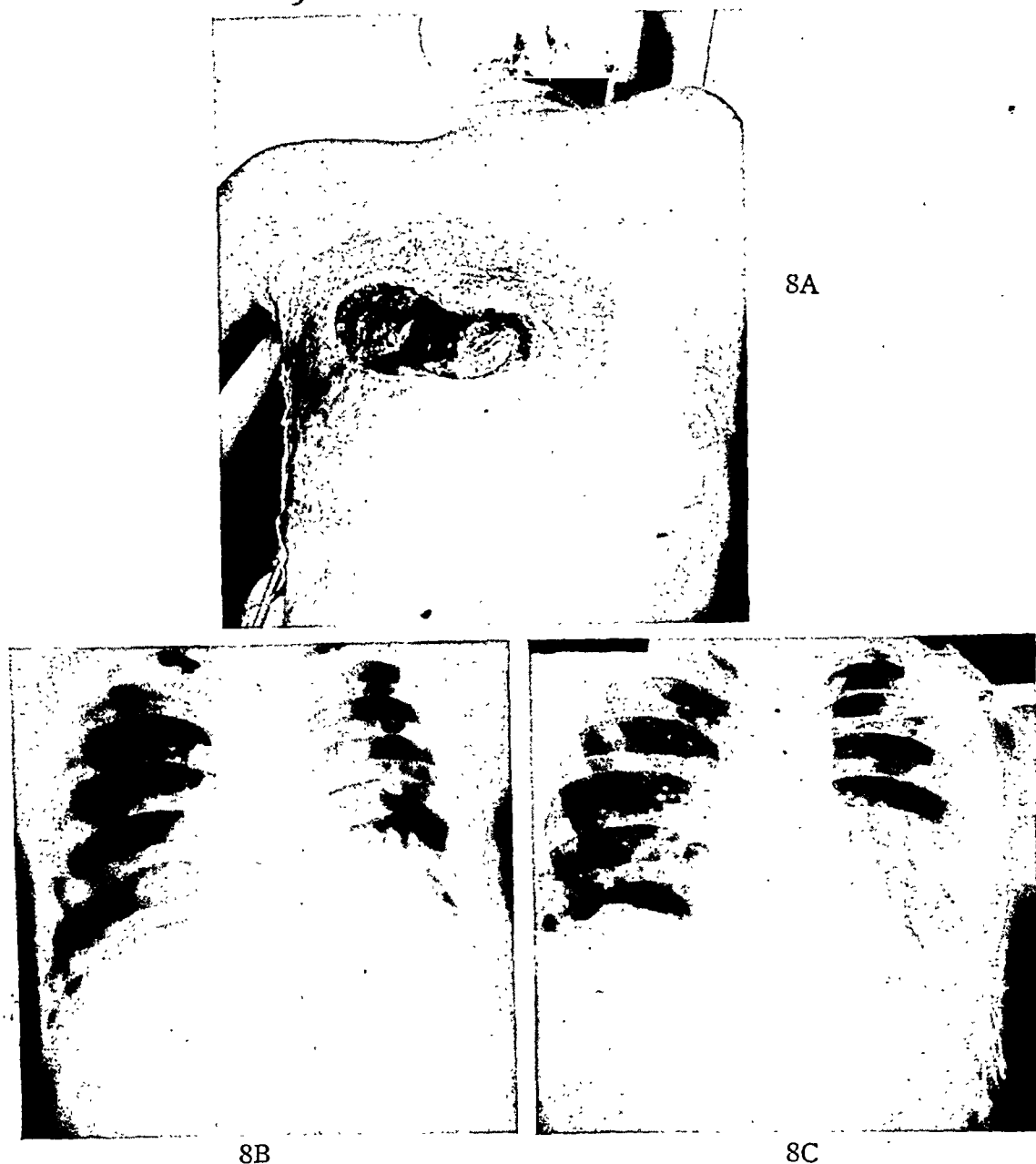


FIG. 8.—(A) This picture was taken three weeks after this patient was admitted with an open sucking infected wound. *Clostridium welchii* infection was present. Suture of the wound was out of the question. After cutting away the dead tissue, the wound was sealed by packing with gauze lightly and sealing it by gluing a sheet of rubber tissue over it to the skin. An interrib catheter was previously inserted and attached to continuous suction so that the negative pressure would pull the rubber tissue down against the skin and make an effective seal. At this time the lung had become almost completely reexpanded and fixed to the parietal pleura.

(B) Roentgenograms taken soon after insertion of the interrib catheter, when only 10 cm. of water negative pressure was applied.

(C) After a few days the suction was increased to 150 cm. (water) negative pressure. Within a month of the time he was injured the lung had been reexpanded and the cavity was only the size of the tube.

it was demonstrated that an infected cavity was present around the foreign body but it drained into the bronchus or the pleural cavity, so that a typical lung abscess did not occur. In three patients there was putrid empyema early in the disease which possibly may have developed on this basis. In one case an abscess around a foreign body obviously ruptured into the pleura to give an empyema when a pneumohemothorax had previously been present.

The patients who had large foreign bodies in the lung usually had some persistent cough with the expectoration of some mucoid material. Three of the patients had persistent sinuses which healed only after the removal of the foreign bodies. Only one patient had a massive pulmonary hemorrhage (Fig. 9). This occurred about two months after injury at a time when he

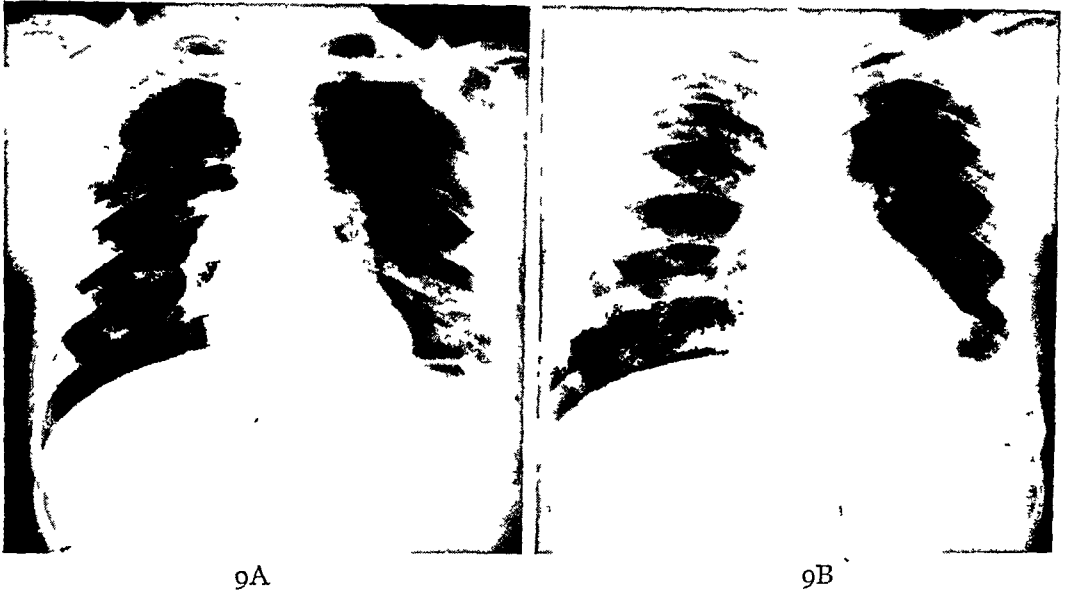


FIG. 9.—(A) This picture was taken about a month after the original wound. The hemopneumothorax had responded to thoracentesis. A sinus persisted at the site of the wound of entrance in the left midaxillary line. While hoping for this sinus to close the patient had a massive pulmonary hemorrhage. This was about two months after the original injury, and the patient was otherwise perfectly well.

(B) Two days following the hemorrhage the fragment was removed. The cavity in the lung was packed for fear of further bleeding. The drain was out in two weeks. Within a month the lung had cleared. The patient returned to duty.

was well except for a persistent sinus and cough, and was awaiting operation. The foreign body was removed two days later, with an uneventful recovery. The patients with small foreign bodies were usually asymptomatic.

A metallic foreign body which becomes encysted in the lung is in the center of a granulating cavity. It seemed likely that sooner or later a number of the larger and more irregular foreign bodies would be associated with infection or hemorrhage. It is impossible to say which foreign body is likely to cause trouble. For this reason an arbitrary standard was set of 1 to 1.5 cm. All foreign bodies over that were to be removed and all under that were to be left alone. With a few exceptions this policy was followed.

Five of the foreign bodies stopped in the mediastinum. Only one appeared to be in close proximity to a large vessel, and was removed. The other four

seemed no more likely to cause trouble than metallic fragments elsewhere in soft tissue. They were observed for a month before return to duty.

#### REMOVAL OF FOREIGN BODIES

Twenty-three of the 61 patients with retained foreign bodies in the thoracic cavity were subjected to operative removal of the foreign bodies. Two were operated upon as emergencies because of putrid empyema. One was removed from the pericardial sac because of effusion with tamponade and cardiac failure. One was removed from the free pleural cavity because of persistent effusion. One was removed from the mediastinum. The remaining 18 were removed from the lung as more or less elective procedures.

The patients were allowed to recover as completely as possible from their wounds before removal of the foreign bodies. In those who had no hemothorax the operation was usually undertaken from three to four weeks after injury. Those who had hemothoraces were treated by thoracentesis and allowed to recover from it before the foreign body was removed, four to eight weeks after injury. There seemed to be no reason for doing this elective operation before the patient was in the best possible condition.

The removal of the foreign bodies was found to be simpler than anticipated. No serious difficulty was encountered in any of these patients, and there were no deaths in this group. A very important point was proper localization of the foreign body. In addition to obtaining anteroposterior and true lateral roentgenograms, the patients were examined under the fluoroscope and the point marked at which the foreign body was nearest the skin.

The patients were operated upon under endotracheal anesthesia, with controlled respirations. An intercostal incision was used. There were usually adhesions present, especially when there had been an hemothorax. The general area of the site of the foreign body could be ascertained by the indurated mass in the lung. It was frequently necessary to free the lung considerably in order to feel this. In any event the lung was always freed sufficiently so that the involved area could be compressed between the fingers in the event that troublesome bleeding was encountered upon incising the lung. The bleeding was minimized if the incision could be made through the scar of the wound of entrance into the lung. The freed lung containing the indurated area was then taken between the fingers and a 22-gauge needle was inserted to locate the foreign body exactly. The lung was then cut open and the foreign body removed. The greatest care had to be exercised when the foreign body was near the hilum of the lung for fear of cutting one of the large vessels (Fig. 10).

In about one-half the patients the cavity in the lung appeared to be clean, so that the opening in the lung was sutured and the chest closed without drainage. In the other half a drain was used because there was some purulent material around the foreign body. When hemorrhage from the cavity was feared, dry gauze was inserted into it and brought out alongside of the drainage tube in the pleura.

Oral prophylactic sulfonamide therapy was administered routinely both pre- and postoperatively. Penicillin was available for use only in the last



part of the campaign. Spreading infection did not occur in any instance, and the tubes were all out within two weeks. In one patient a pure culture of *Clostridium welchii* was obtained from the cavity around the foreign body. The wound was drained and no trouble encountered. There were almost no complications. Two patients had sufficient bronchial secretion to require tracheal aspiration because of atelectasis. Two patients had small stitch abscesses, but no patient developed infection in the lung or pleura.

The roentgenographic appearance in these patients cleared completely (Figs. 9, 10 and 11), and they apparently had excellent results. All of these patients returned to duty.

#### WOUNDS OF THE HEART AND PERICARDIUM

Only four patients in this series had recognizable wounds of the heart or pericardium. One was admitted 12 hours after a 25-caliber bullet perforated his left ventricle, left lung, and spleen. At operation, the perforation of his heart was sutured and the spleen removed, but he died 48 hours later.

One patient with a large right hemothorax had the shell fragment lodged in the pericardial sac behind the heart. He developed marked signs of cardiac failure three weeks after his injury, incident to slow tamponade. The foreign body was removed. The pericardial collection was sterile. He made a rapid and uneventful recovery.

The other two patients were operated upon also. One for a purulent pericarditis following a bayonet wound. The other had a pericarditis following a shell fragment perforation of the tip of the heart but probably not of the cardiac cavity. Both of these patients recovered.

#### THORACO-ABDOMINAL WOUNDS

There were 46 patients with thoraco-abdominal wounds. In some instances this was a single wound which traversed the diaphragm while in others there were multiple wounds involving both the chest and abdomen. In this group there were nine deaths, a mortality of 20 per cent. Only one of these patients died from the chest wound. The remaining eight patients died of peritonitis, or complications of it.

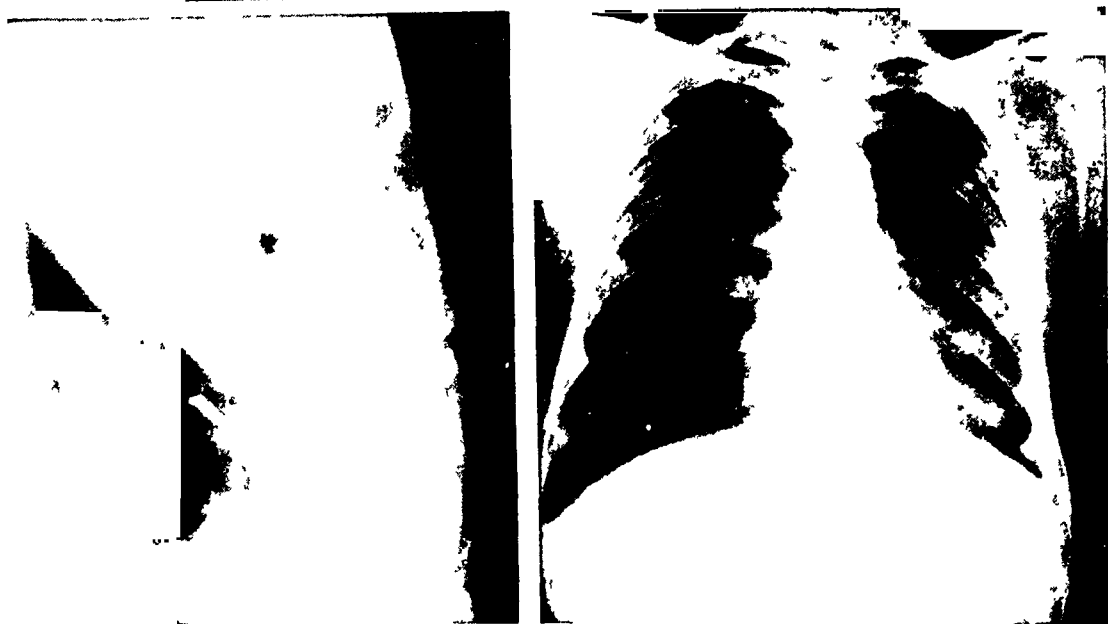
The patients with wounds in the right side, where the liver was the only abdominal organ involved, did very well. In two patients, operated upon at the portable surgical hospitals, the diaphragm was sutured to the chest wall above a low penetrating wound of the right chest in order to close the pleural cavity. They did well.

#### MORTALITY

The total number of deaths in this series of 308 patients, regardless of the associated injuries or diseases, and regardless of the cause of death, was 23, a mortality of 7.4 per cent. Twelve of these had insignificant chest wounds and died of major abdominal or cerebrospinal wounds. Five of the patients obviously died of associated injuries or diseases, although in some the chest wound may have contributed to the patients' general poor condition. Only six patients, 2 per cent of the total series, died primarily of their chest wounds.



10A



10B

10C

FIG. 10.—(A and B) A 25-cal. rifle bullet entered through the sternum and lodged in the hilum of the left upper lobe. As shown in the lateral view there was some atelectasis of the lower lobe. This cleared with bronchial aspiration. Later, detailed roentgenograms showed some cavity around the bullet. The patient had a cough productive of mucus but ran no fever.

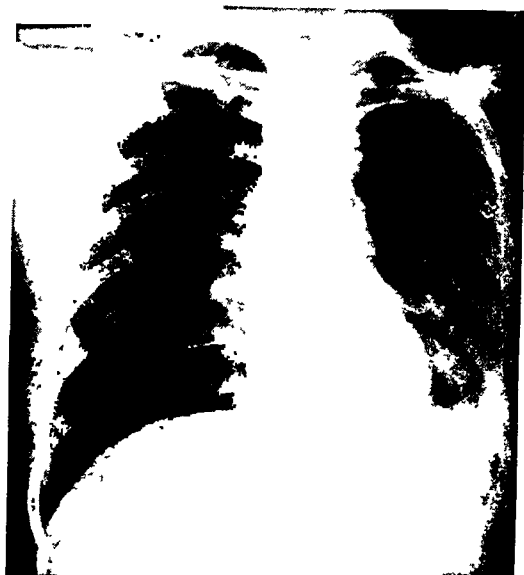
(C) The bullet was removed as an elective procedure two months after injury. An intercostal incision was used. The bullet was removed from between the branches of the artery to the upper lobe. The patient had an almost perfect result, and returned to duty.



11A



11B



11C

FIG. 11.—(A and B) These pictures were taken one month after the patient was wounded. He had recovered uneventfully from an hemopneumothorax treated by repeated thoracenteses. A high fever at the outset had subsided.

(C) At operation, purulent material was found around the shell fragment. A pure culture of *Clostridium welchii* was obtained. The lung was drained. The convalescence was uneventful except for about four days of fever. This film, taken one month after operation, shows complete clearing of the lung. He returned to duty.

At the beginning of this campaign it was felt that if a patient with a wound of the thoracic cavity survived to reach this hospital, he should not die of his chest wound unless he developed overwhelming pulmonary infection or had some unusual accident. It seemed reasonable to hope that with adequate treatment no patient should die from a disturbance of his respiratory mechanism and that by careful watching and timely intervention no patient should die of empyema. These ambitions were not quite realized.

Of the six patients who died primarily of their chest wounds, one did die of a disturbance of his respiratory mechanism. He was first seen 48 hours after injury. His wound was still sucking. He had suffered for 48 hours from inadequate aeration and an inability to cough up the blood and mucus in his lungs. In spite of reëxpansion of the lung by the insertion of a catheter with suction, tracheal aspiration, and transfusion, he died within three hours. The second patient died from the perforating wound of the heart, lung and spleen. The third died from a cerebral air embolus, proved at autopsy, incident to an insignificant wound of the lung. The fourth was also believed to have died of a cerebral air embolus, but no autopsy was done. The remaining two died of multiple lung abscesses.

DISCUSSION.—Once the patient with a wound of the thoracic cavity is over the immediate threat to life from blood loss or altered respiratory physiology, the chief objective in treatment should be the complete restoration of function. During the observation and treatment of this series of patients it became increasingly apparent that the most important factor in the complete restoration of function was the early reëxpansion of the lung in the patients with pneumothorax or empyema. On the basis of the experience with this group of patients, it seems evident, that early thoracentesis is the treatment of choice for the patient with hemopneumothorax.

A few patients whose hemothoraces could not be aspirated by thoracentesis because of clotting were treated conservatively early in the campaign. This was a mistake. Open operation with evacuation of the blood clot and decortication of the lung is certainly the treatment of choice.

As experience was gained during the course of this campaign it became increasingly apparent that unless an empyema was small, the best result was obtained by early operation, under endotracheal anesthesia, without waiting for fixation of the mediastinum, evacuation of all exudate, and rapid reëxpansion of the lung by the application of an high degree of negative pressure.

#### CONCLUSIONS

1. A series of 308 patients with battle wounds of the thoracic cavity were admitted to a General Hospital during a period of 16 months. This was an unusual opportunity, in that the patients were evacuated to this hospital as rapidly as the circumstances of the campaign would permit (over 50 per cent within 36 hours), and that, with few exceptions, they were treated in this hospital until they had completely recovered.

2. The personnel of the Portable Surgical Hospitals who operated upon

these patients early, under the most trying conditions of jungle warfare, are responsible, to no small degree, for the excellent results.

3. The total mortality in this series, regardless of the associated injuries or diseases, was 7.4 per cent. In only 2 per cent (six patients) could the death be attributed to the chest wound.

4. The treatment of choice for hemopneumothorax is the rapid reëxpansion of the lung by repeated thoracenteses. When the hemothorax is clotted (8 per cent of hemothoraces in this series) thoracentesis is not effective. In the presence of this complication thoracostomy, with evacuation of the blood clot and decortication of the lung, is the most effective method of bringing about rapid reëxpansion of the lung and complete restoration of function.

5. Simple tracheotomy is suggested as a treatment for wounds of the trachea with mediastinal and subcutaneous emphysema. It is probable that by eliminating the tremendous increase in intratracheal pressure during coughing, the forcing of air into the mediastinum will be stopped in most instances.

6. The incidence of empyema was 9.7 per cent (30 patients). Infection within the lung was a major problem in only two patients. The early and routine use of sulfonamides probably played an important part in almost eliminating serious spreading infection. Penicillin was not available for prophylactic use in these patients.

7. The primary objective in the treatment of an empyema should be the early and complete reëxpansion of the lung. A method of treatment is described. A large opening was made in the chest and the fibrous exudate completely removed. By means of an air-tight seal this was then converted into closed drainage. The application of an high degree of negative pressure (150 cm. of water) was very helpful in bringing about the rapid reëxpansion of the lung. Especially in the presence of a large empyema, it is recommended that this be done early, using positive pressure anesthesia, without waiting for the fixation of the mediastinum.

8. Twenty-three of 61 foreign bodies retained in the thoracic cavity were removed. The technic used is described. The simplicity of the procedure and the excellent results obtained in this series, suggests the routine removal of large foreign bodies from the lung. It is recommended that when undertaken as an elective procedure, the patient should be allowed to recover from his wound as completely as possible before being operated upon for the removal of the foreign body.

#### REFERENCES

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- <sup>2</sup> Johnson, J.: Total Pneumonectomy. *Surg., Gynec. & Obst.*, 76, 460, 1943.

# THE "WET LUNG" IN WAR CASUALTIES

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EXPERIENCE gained in treating a large number of casualties in the Sicilian and Italian campaigns prior to July 1944, has shown the importance of the "wet lung" in reference to the morbidity and mortality of patients with wounds of the chest, brain and abdomen. The authors' combined experience consisted in the management of over 770 casualties in which the chest wound was the primary concern as well as the thoracic complications that arose in over 3,000 other casualties of all types. These cases were treated both in forward surgical installations as well as in a Base Hospital designated as a Thoracic Surgical Center in the North African Theater of Operations (NATOUSA). (We have found no reference in the literature prior to the studies now in publication from this group.) Because of the importance of wet lung in war casualties, it seems desirable that a thorough discussion be presented at this time.

## DEFINITION

In handling this large number of casualties it was found in the Forward Hospitals in particular, that those cases with dry lungs gave us very little trouble. On the other hand, those showing a wet pulmonary tree were difficult to resuscitate from shock. They were poor operative risks for emergency surgery and most frequently developed pulmonary complications. In the chest wounds the mortality was highest in this group. In fact, no more serious problem was encountered by the surgeons in Forward Hospitals treating thoracic wounds than the therapeutic problem of the wet lung. Gradually we realized that it was necessary to pay more and more attention to this type of patient. This concept of the wet lung developed after a year's study of the problem. By wet lung is meant the persistence of fluid in the pulmonary tree. This fluid may be present in various forms—mucus, blood, serum, *etc.* The forces which favor the persistence of moisture in the pulmonary tree are mainly the results of trauma. The presence of fluid in the bronchial tree is of most importance early, as it promotes anoxia, and late, as it paves the way for subsequent pulmonary complications.

## CAUSATIVE FACTORS

There are two groups of factors which are important in the development of wet lung: 1. Forces leading to the production of secretions and other fluids in abnormal amounts in the respiratory tract. 2. Conditions preventing adequate removal of the fluids so produced. In war casualties many conditions

are present which favor both the accumulation and inadequate expulsion of fluid material from the pulmonary tree.

Mucoid secretions may be present in abnormal amounts in the bronchial tree as a result of increased secretory activity of the bronchial mucosa. This has been observed clinically in many battle casualties. Experimentally, de Takats, and his associates,<sup>1</sup> have shown that any appreciable trauma to the chest wall was followed almost immediately by widespread bronchial spasm and increased bronchial secretion in 60 per cent of the animals tested. Abdominal stimuli, such as traction on the cystic duct or mesentery, produced similar bronchial findings. Just how long this bronchial secretion and associated spasm continues is not definitely known. Clinically, we have observed wet lung for several days following injury, although other factors producing "moisture" in the pulmonary tree were undoubtedly present.

Blood from intrapulmonary hemorrhage is present in the bronchial tree in varying amounts and may cause bronchial obstruction. Clinically blood appears to be irritating to the bronchial mucosa and causes increased bronchial secretion. Mucopurulent secretions from upper respiratory infections and bronchitis are not uncommonly present in the bronchi of soldiers undergoing the exposure of combat conditions. Bloody fluid from an hemothorax may also be present in the bronchial tree as a result of spillover through a bronchial fistula.

Fluid arising in the alveoli of the lung also produces obstruction of the pulmonary air-way and presents a difficult clinical problem. The mechanism of production of pulmonary transudates and exudates in the severely injured is not well understood. Some of the factors are known and will be briefly enumerated. It is generally established that there is local extravasation of plasma at the site of injury following trauma. Thus, damage to pulmonary tissue would result in the leakage of plasma as well as blood into the alveoli in the injured portion of the lung. The experimental work of Drinker and Warren<sup>2</sup> has shown that tracheal obstruction produces pulmonary and pleural transudates and exudates containing red blood cells. Severe respiratory movements were similarly found to lead to the formation of pulmonary transudates. Their studies further showed that anoxia was a potent factor in altering the permeability of the pulmonary capillaries resulting in the leakage of plasma fluid. Thus, early there are four known factors which have an important bearing on the escape of fluid from the pulmonary capillaries into the alveoli and bronchial radicles: (1) Pulmonary trauma; (2) increased respiratory effort; (3) tracheal obstruction; and (4) anoxia. Blast injuries of the lung are known to produce hemorrhage in the terminal divisions of the pulmonary tree and may present important additional factors in the production of alveolar transudates. In the late stages of shock the capillary permeability is increased in nontraumatized regions of the body so that blood plasma escapes into the tissue spaces. That which escapes into the pulmonary alveoli results in the clinical findings of pulmonary edema. The clinical significance

of the interaction of these conditions which are present in severely injured patients, especially those with thoracic trauma, will be discussed later.

In order to understand the factors leading to inadequate expulsion of fluids formed in the pulmonary tree, one must analyze the normal cough mechanism. There are four main factors. First, there is the voluntary drawing in of air into the lungs of the conscious patient by raising the ribs and lowering the diaphragm. The breath is then momentarily held by closing the glottis. The abdominal muscles are tensed, the intercostal spaces are narrowed, and the diaphragm relaxed to give the expulsive force. The sudden opening of the glottis results in releasing the bechic blast necessary to raise the sputum. Chest pain arising in the chest wall or pleura prevents both expansion and forceful contraction of the thorax. This potent factor in preventing successful cough is present in varying degrees in thoracic injuries. In the same way, wounds causing abdominal pain prevent the tensing of the abdominal muscles necessary for effective cough. When the diaphragm is acutely injured or pushed up by distended intestines or a dilated stomach, the piston-like action is impaired and cough is ineffectual.

Rib fractures are frequently the source of severe thoracic pain when cough or deep breathing is attempted. However, when there are multiple fractures of ribs or sternum resulting in a so-called "flail chest" the added factor of the paradoxically moving chest wall is present. On inspiration the chest wall falls in, due to the negative intrathoracic pressure, while on expiration the thoracic cage moves out. Attempts at coughing exaggerate the paradoxical movement of the chest wall, and the resultant cough is very ineffectual. Because of severe pain experienced with fractured ribs and "flail chest," oversedation with morphine is not uncommon. The standard army "syrette" of morphine tartarate is put up in 0.5 grain tubes. Not rarely a patient with a "flail chest" or other severely painful thoracic or abdominal wound arrived in the Field or Evacuation Hospital shock ward in a semicoma with cyanosis and infrequent respirations, the direct result of the reception of two full syrettes of morphine (1 gr.) in the space of a few hours. This is partly due to the dyspnea and anxiety of the patient, who calls for more sedation, and also because the recording of every medication on the field medical record is sometimes very difficult under field conditions. The patient may receive a second injection of morphine because there is no record of the first. Shock officers of the Field and Evacuation Hospitals must be constantly on guard to avoid overdosage with morphine of the recently admitted patient, who may be apprehensive as the result of anoxia and is anxious and upset by the ambulance ride. Oversedation with opiates for any type of wound leads to a decrease in the cough reflex and promotes the accumulation of secretions in the bronchial tree.

In a like manner skull wounds producing coma and the unconsciousness resulting from shock permit the pooling of fluid in the bronchi. The prolonged administration of anesthesia to those in poor condition, followed by delayed reactivity of the patient, may lead to the retention of bronchial secre-



tions, and postoperative pulmonary complications are prone to develop. Upper respiratory infections were common among soldiers living under field conditions during the winter months of the 1943-44 Italian Campaign. This was aggravated by the exposure accompanying their litter-carry down from the mountain tops. Frequently 6-12 relays of litter carries were necessary to get the wounded men down to the Collecting Station, a trip often consuming 12 hours. Because of pain experienced in movement, the wounded man tends to lie constantly in one position, which promotes the gravitation and retention of secretions in the dependent portions of the lung.

#### HARMFUL EFFECTS

(A) *Early*.—The presence of fluid in the respiratory tract of the acutely injured patient has an important bearing on his state of shock and recovery therefrom. We have considered how blood, mucoid secretions, aspirated material, and transudates may be present in the pulmonary tree. The presence of this obstructing matter prevents adequate intake of oxygen to the alveoli. This results in less oxygen being available for the pulmonary capillary and "anoxic" anoxia results. According to the work of Drinker and Warren<sup>2</sup> anoxia increases capillary permeability and, therefore, more plasma tends to be lost into the tissues. Fluid from the pulmonary capillaries extravasated into the alveoli again decreases the oxygen available for the blood stream. In the advanced state, we have a clinical picture which cannot be differentiated from pulmonary edema seen in other conditions. Thus, the persistence of fluid substances in the pulmonary tree aids in the establishment of a vicious cycle that tends to increase the degree of the shock. We have seen shock unrelieved by the standard measures of "replacement therapy" with blood and plasma until the treatment of the wet pulmonary tree brought the patient out of his extremely precarious condition. If sufficient attention is not paid to the wet lung with its resulting anoxia, serious changes in other organs will take place. Most sensitive is the central nervous system, where severe cerebral anoxia over a short period of time may result in marked cortical impairment. Psychotic manifestations and coma which were, in the main, caused by cerebral anoxia were occasionally seen in our series of cases.

Plugging of a branch bronchus allows no exchange of gases in the lobule supplied by this bronchial division. With the absorption of the oxygen by the pulmonary capillaries "lobular atelectasis" may be produced. Of course, complete plugging of a branch bronchus to a lobe or stem bronchus to one lung would increase the anoxia and shock, not only due to the decrease in the alveolar bed available for the absorption of oxygen, but also to the associated mediastinal shift.

(B) *Late*.—If the patient is not too severely wounded, he may recover from the primary shock without complete relief of the obstruction of the pulmonary tree, there may be recurrence of the obstruction due to the factors previously mentioned. The stage is now set for the development of atelectasis, pneumonia, and tracheobronchitis.<sup>3</sup> These conditions develop in a manner similar to the postoperative pulmonary complications seen in civilian life. The

same etiologic factors are involved. There is the abnormal presence of secretions and the like in the bronchial tree, and also there are similar influences preventing the expelling of this obstructing material. In the medical literature of the past decade great emphasis has been placed on the importance of the unrelieved obstruction of the bronchi as the etiologic factor in the development of these conditions in the postoperative patient. It is not necessary for us to review all of this evidence. However, we would like to particularly emphasize that in atelectasis and pneumonia following trauma to the chest, brain or abdomen there are a similar train of developmental circumstances. We have seen two cases of typical total pulmonary atelectasis admitted to the shock ward of a Forward Hospital which we believe were similar to the cases of "massive pulmonary collapse" reported in World War I. In our patients the atelectasis was clearly the result of bronchial obstruction from retained blood clots and mucus. The atelectasis cleared rapidly with the relief of the bronchial obstruction in each case. Although atelectasis and pneumonia are not uncommon following trauma, lung abscesses are extremely rare. There has been no case in our series, although several have been reported in this theater of operations.

#### SIGNS AND SYMPTOMS

The presence of abnormal amounts of fluid substances in the bronchial tree may be detected by certain cardinal signs and symptoms. The recognition of the syndrome in its earlier stages should lead to vigorous treatment, which will often prevent the development of graver complications. One of the most frequent findings is an almost constant "wet cough." Such a cough may even have a rattling element, which persists in spite of the fact that sputum is being raised with each effort. The wheeze or rattle continues because the sputum is being inadequately expelled, or there may be associated bronchospasm. The cough may be continuous, hacking, or more paroxysmal in character and the expulsive force is often weak. Occasionally the cough may be nonproductive in spite of strenuous efforts. When small amounts of sputum are being raised with constant repeated coughing attacks, one is tempted to infer that the drainage is adequate—a fallacious assumption. Auscultation of the lungs after coughing will reveal râles, which are evidence of incomplete tracheal drainage. This type of cough indicates that only the most superficial secretions are being raised. Thus, a cough that is continual and more or less productive is most frequently a sign of inadequate bronchial drainage.

On physical examination there are two outstanding features: dyspnea and bronchial râles. If there has been considerable thoracic trauma the dyspnea is usually due to a combination of various factors (hemothorax, mediastinal shift, *etc.*). Dyspnea may be due to painful respiration, which is of the jerky, shallow type, each inspiratory effort being limited by the pain produced. But where the thoracic damage has been minimal or in cases of abdominal or cranial injury, dyspnea frequently may mean partial bronchial obstruction with resultant anoxia. Present in practically all these cases are râles varying from high pitched wheezes (which may be evidence of associated bronchial

spasm) to medium or coarse bubbling râles. Râles may not be elicited on the examination of the patient unless auscultation is made immediately *after* coughing. Frequently sticky mucus attached to the tracheal or bronchial wall or the completely obstructed branch bronchus will not present the physical sign of râles. Fine crackles heard with the stethoscope over the patient's mouth on respiration is a sensitive index of moisture in the bronchial tree. In the early cases, the evidence of moisture heard by the stethoscope is the most important physical sign.

In the advanced cases the diagnosis is usually simple and can be frequently made at a distance by the dyspnea and audible râles. Tachycardia, cyanosis, and varying degrees of shock and even coma may be present. Psychotic manifestations due to cerebral anoxia are not uncommon. The late findings of unrelieved bronchial obstruction are those of atelectasis and pneumonia, usually associated with fever.

The character of the sputum is of diagnostic significance. Bronchial secretions assumed to arise as a result of reflex stimuli from chest trauma, irritation from aspirated material, or early infection are of a mucoid type. As infection develops in the bronchial tree, the sputum becomes more and more purulent. Hemoptysis of course usually denotes pulmonary injury. Depending on whether fresh blood or clots mixed with mucus are present, the hemorrhage is either recent or old. If thin serosanguineous fluid is raised, one must suspect an hemothorax with bronchopleural fistula. While similarly thin seropurulent sputum may point to an early empyema with bronchopleural fistula. Thin yellow, pink or colorless sputum, often mixed with air to give it a frothy appearance, is evidence of the pulmonary transudation and exudation (edema) seen in the severe cases. The sputum from the majority of patients presents a mixture of these various types.

#### ROENTGENOGRAPHIC FINDINGS

When the casualty arrives in the Field or Evacuation Hospitals in shock or with wet pulmonary tree, these conditions must be strenuously treated before any roentgenologic examinations are made. The frequent coexistence of extensive thoracic wall, pleural, or intrapulmonary pathology makes the shadows due to partial or complete bronchial obstruction very difficult to interpret (Case 4). In the early stages of the wet lung, roentgenographic findings are minimal and a considerable degree of obstruction may be present without roentgenographic evidence. Roentgenograms in two planes should be taken whenever possible. When any question arises more weight should be placed on the clinical picture. In certain instances, the information gained by the taking of intrapleural pressure readings, aids in the interpretation of the roentgenographic findings (Case 4). Patchy lobular atelectasis is seen early in these cases and may be indistinguishable from shadows cast by pulmonary hematoma. Later, when lobular or total pulmonary atelectasis is present, the collapse of these parts of the lung produces the classical signs of mediastinal shift and narrowing of the intercostal spaces.

TREATMENT

(A) *Prevention*.—It is important to regard every patient with a chest wound or a severe abdominal or brain injury as a potential candidate for the development of wet lung. We must keep as our objective the maintenance of an open pulmonary airway so that inspired oxygen can be made available for the alveolar capillaries. In the vast majority of instances, this may be accomplished by the prompt employment of simple preventive measures. The patient is rapidly made a fit candidate for early emergency surgery, and the undesirable sequelae previously discussed are avoided. Only those procedures that are of importance to the establishment and maintenance of an adequate bronchopulmonary air-way are considered, as the general treatment of shock is outside the limits of this communication.

On admission, all casualties with chest injury and with history of dyspnea, hemoptysis, wheezing, cough, or thoracic pain are examined carefully for signs of fluid retained in the pulmonary tree. Patients with severe abdominal or cerebral wounds must also be carefully followed from this point of view. Unless in shock or unconscious, all patients are placed in Fowler's position, in which the gravitation of abdominal contents downward allows the diaphragm to work more efficiently, both for breathing and effective coughing. When cyanosis or dyspnea is present, oxygen is administered by nasal catheter or the more efficient B.L.B. mask. If the breathing is wet the patient is encouraged to cough by manual support of the chest. It is not only the actual support of the painful chest wall that aids these patients. The patient is encouraged to cough and cannot help but be impressed with its importance when some one takes the time to come around to assist him. Small doses of morphine, judiciously employed, are of value. Doses of  $\frac{1}{6}$  grain are the rule. Sometimes  $\frac{1}{8}$  grain suffices, but we never used over  $\frac{1}{4}$  grain. We prefer to administer the morphine intravenously as its action is more rapid and the effect can be more accurately evaluated.

Such measures as the aspiration of blood from an hemothorax or air from a pressure pneumothorax must be employed to increase the vital capacity. The dressing on "sucking wounds" should be so fixed that air is not sucked in through the chest wall opening during this period of resuscitation of the patient. Gastric distention, which may greatly immobilize the diaphragm, must be dealt with by means of the stomach tube. It is most important to correct these pathologic conditions promptly, as they contribute to the dyspnea, anoxia, and shock.

(B) *Active Measures*.—1. *Intercostal Nerve Block*: If the patient does not clear his bronchial tree by coughing then additional measures must be employed. Respiration is limited and cough is ineffectual if chest pain is not relieved. The abolishment of painful and other stimuli arising in the chest wall and parietal pleura may be all that is needed to effect successful clearing of the pulmonary tree. Rovenstine and Byrd,<sup>4</sup> and Harmon, *et al.*,<sup>5</sup> have reported the use of nerve block and local procaine infiltration to control chest wall pain. The technic of intercostal nerve block is simple. In brief, 5-10 cc.

of 1 or 2 per cent procaine are injected around the intercostal nerves supplying the traumatized area of the chest. To insure relief of pain, one must inject several intercostal nerves above and below those innervating the traumatized area. Pain and discomfort have been abolished for periods of time averaging not less than 24 hours (Case 1). Why the relief of pain extends beyond the pharmacologic action of procaine is difficult to explain. Relaxation of muscle spasm and improvement of the blood supply to the traumatized region may be important factors. The nerve block should be repeated as often as is necessary. If a large number of nerves need to be injected a small dose of a barbiturate should precede the injection, so that there is lessened danger of procaine reaction.

In all of our cases, with the exception of one severe case of flail chest, in which there were multiple fractures of six ribs, blocking of the intercostal nerves had made strapping of the thorax unnecessary. Tight bindings of the chest is unphysiologic, as it limits respiration and favors the retention of secretions. Frequently the patient breathes more comfortably without his chest strapped than with the strapping in place. However, in case of extreme paradoxical movement of the thoracic cage, prevention of the ballooning out of the chest wall by a firm binder may be necessary in addition to the nerve block.

Intercostal nerve block is of value not only to relieve pain but also to block stimuli that may cause reflex disturbances in the bronchi. The part played by reflex constriction of the bronchial tree and secretion of mucus, as shown experimentally by deTakats,<sup>1</sup> should not be overlooked. We have seen patients with chest injuries, in respiratory distress and in whom severe chest pain or shock was not the predominating factor. There was no evidence of blood in the bronchial tree, exposure to a noxious gas, infection, nor aspirated material. Wheezing, which we believe represented both bronchial spasm and mucus secretion, persisted after coughing (Case 2). Following intercostal nerve block there was cessation of wheezing and the raising of mucoid sputum. Here, the blocking of the chest wall stimuli seemed to relieve the reflex bronchial spasm and mucus secretion. It is true that usually we have a combination of the factors previously discussed, nevertheless, intercostal nerve block may be used to minimize "reflex" bronchial spasm and mucus secretion where there is chest wall and parietal pleural injury, even though pain is not prominent.

At open thoracotomy, advantage should be taken of the opportunity to block the intercostal nerves under direct vision. The nerves may be simply injected with procaine or crushed with a fine hemostat. This is an important procedure as it provides the relief of pain and diminishes the stimuli arising from the chest wall and parietal pleura during the important postoperative period. It also obviates the necessity for intercostal nerve block following surgery.

That reflex spasm of the bronchus and secretion of mucus by the bronchial glands can be initiated by thoracic injury has been shown by deTakats. Though the evidence is in nowise conclusive, certain of our clinical observations seem to substantiate the experimental findings of this worker. If this

is so, one would expect atropine to abolish these vagal impulses. However, deTakats<sup>1</sup> found that atropine prevented bronchospasm in only 20-42 per cent of the experimental animals, even though tremendous dosages, up to  $\frac{1}{6}$  grain, were employed. Our clinical experience with the use of atropine in these cases so far has presented conflicting evidence.

2. *Catheter Aspiration*: The measures enumerated above are continued as long as there is clinical improvement. If the patient does not improve or if there is evidence of inadequate raising of sputum, mechanical aspiration of the bronchial tree is resorted to without delay.<sup>3</sup> This may be performed by one of two methods—I. Catheter aspiration, as described by Haight.<sup>6</sup> 2. Bronchoscopy. In both, the basic aim is the removal of excess secretions in the lower air-way.

The equipment for catheter suction is almost always available and the technic is simple. With practice, anesthesia is rarely necessary so that this method can be most easily used in an emergency. The mastering of this technic by all those treating injuries of the chest, brain, and abdomen will result in the saving of many lives. Local anesthesia is indicated in certain cases with hyperirritable gag reflexes. Two per cent pontocaine or 5 per cent cocaine may be sprayed into the pharynx and painted into the hypopharynx with a curved swab or applicator. A small dose of barbiturate should be administered before the pontocaine or cocaine is used. No fluids should be ingested until the gag reflex has returned.

A source of suction delivering 15 pounds of negative pressure, a fairly stiff No. 16 or 18 urethral catheter of the Robinson type, and connecting tubing are all the materials necessary. One of us<sup>7</sup> has designed a portable hand suction machine which has proved of great value in the forward surgical installations, where electricity or electrical suction machines were not always available. An attachment to the windshield wiper or the gas intake manifold of motor vehicles may be used as an emergency source of suction.

The patient is placed in Fowler's position, the neck is flexed, and the tongue pulled rather sharply forward to anchor the larynx. If the patient is unconscious, the index finger of the left hand can engage the tip of the epiglottis so that the catheter is very easily passed through the larynx. In conscious patients the catheter is passed through the nostril and advanced until the larynx is reached. The catheter is then withdrawn for about one centimeter and the patient asked to take a rapid deep breath. During inspiration the catheter is quickly advanced into the trachea. Success of the maneuver will be signified by coughing, passage of air through the catheter, and hoarseness of the voice. Hoarseness of the voice is the best criterion, as we have introduced the catheter into the esophagus and noted free flow of air around the catheter in a manner simulating respiration. After the catheter has been advanced for several centimeters into the trachea, suction is begun. (Suction should not be applied until the catheter has passed the larynx). The patient is urged to cough and usually does so forcibly, due to stimulation of the tracheal mucosa. The catheter is slowly advanced and withdrawn to provoke coughing and pre-

vent excessive suction on the mucosa at any one spot. Suction is not continued for longer than five seconds at a time to allow the patient to rest. After the trachea is dry, the stem bronchi are aspirated. To enter the right stem bronchus the patient's head is turned slightly to the left. It is somewhat more difficult to enter the left stem bronchus. The patient's head must be turned far to the right and the chin somewhat elevated. The catheter should be advanced as far as possible in each stem bronchus. Frequently, the patient is rolled on his side, with the more involved lung uppermost, so that gravity will aid in draining the small bronchi. Often more sputum is coughed up around the catheter than is aspirated through the catheter. Following catheterization the patient coughs with greater efficiency because of increased ventilation. He should be watched closely however for further accumulation of secretions. Since there is no appreciable trauma to the larynx and bronchi, catheter aspiration may be repeated as often as necessary.

We have left catheters in the trachea for periods of 8-12 hours in patients in whom the rapid formation of bronchial secretions and pulmonary transudates has made aspirations every half hour necessary (Case 3). One hundred per cent oxygen was administered through the tracheal catheter constantly between aspirations. It is surprising how well these patients tolerate the catheter. Subsequent bronchoscopy in these cases showed no evidence of trauma to the vocal cords or tracheal mucosa.

In general, the catheter aspiration of the trachea and bronchi is employed in cases of wet lung whenever assisted cough is not effective. Certain specific uses of bronchoscopy will be mentioned later. All emergency tracheobronchial aspirations should be treated on the wards by the catheter method, facilities for which should be available at all times.

In the comatose patient or one practically "drowning" in his own secretions, catheter suction must be employed at once (Case 3). Delay incurred in getting the bronchoscope ready may result in irreversible changes to the nervous system caused by prolonged anoxia. In these acute emergencies catheter aspiration is frequently a life-saving measure. In postoperative cases, where the civilian experience has been extensive, catheter aspiration has proven itself of great value in the removal of aspirated material or secretions from the tracheobronchial tree.<sup>8</sup> Very rarely, an unusually flaccid epiglottis covers the larynx in such a way that it is impossible to pass the catheter. Catheter aspiration of the bronchial tree has as the chief advantage that it is almost instantly available, does not require the services of a skilled bronchoscopist, and may be used over and over as often as necessary.

3. *Bronchoscopy*: Although bronchoscopy is a highly specialized procedure, usually performed in the operating room, it may be accomplished by the skilled bronchoscopist without moving the patient from the bed. Thus, the fact that the patient cannot be moved does not prohibit the performance of a needed bronchoscopy. General anesthesia is contraindicated in the presence of excess amount of fluid in the pulmonary tree. Topical anesthesia must be employed. No anesthesia is necessary in some instances in semicomatose

or moribund patients. Because bronchoscopy permits direct vision of the air passages, both stem bronchi will be aspirated with more certainty, and mucus plugs blocking the orifices of the branch bronchi will not be overlooked. Curved suction tips may be inserted into the openings of branch bronchi under vision and thus effect more adequate drainage. Similarly, by the direct application of cocaine (or procaine) and epinephrine solutions to the swollen bronchial mucosa the resultant shrinkage of the mucosa further increases the air-way. Thus, bronchoscopic aspiration has the distinct advantage over catheter aspiration of being more thorough.

The decision as to whether to use bronchoscopy or catheter suction following ineffectual cough depends on the individual case. No hard or fast rule can be formulated. If mucus plugs or blood clots in the branch bronchi are expected, bronchoscopy should be performed (Case 4). Thus, bronchoscopy is preferred in proven lobar and total pulmonary atelectasis. Obstruction of the trachea or bronchi that has been present for a period of time should, if possible, be treated with bronchoscopy. If after catheter aspiration, the bronchial tree is still wet, the more thorough procedure, bronchoscopy, is usually indicated.

In cases of bronchial obstruction recurring in spite of repeated tracheo-bronchial aspirations, bronchoscopy is preferred. Frequently, the cause of the recurrence may be found in the fact that catheter suction has not completely removed the obstructive factor. In bilateral processes each stem bronchus is aspirated with more certainty than is possible with catheter suction. When cough is weak and ineffectual there is danger of flooding the contralateral bronchus by sudden releasing of large amounts of sputum from the obstructed bronchus. This may be obviated when the aspiration is performed under the direct vision possible with bronchoscopy. Occasionally there were patients in the forward installations where the bronchial tree remained "wet" due to retained blood or mucus. Emergency celiotomy or thoracotomy was indicated for associated wounds. Here bronchoscopy performed immediately before surgery made the anesthesia much more satisfactory (Case 3). In these cases and, in fact, in all forward thoracotomies and thoracoceliotomies we have routinely performed bronchoscopy immediately following operation. This policy gradually evolved from the difficulty we had in the postoperative management of the severely wounded patients. In the vast majority of instances this postoperative bronchoscopy kept the bronchial tree dry until the patient reacted sufficiently to raise the sputum by his own efforts.

Severely wounded patients in shock should not be exposed to the fatiguing effects of prolonged coughing. Therefore, great care must be exercised to perform the bronchoscopy as quickly as possible, watching carefully for early evidence of tiring. Oxygen, 100 per cent, should be administered through the bronchoscope during the procedure in all patients with anoxia. One must remember that often the sicker the patient, the more he may need tracheo-bronchial aspiration, since his precarious state may be directly the result of obstruction of the bronchial tree.



4. *Positive Pressure Oxygen:* Thus far we have discussed procedures mainly to effect the removal of fluid substances from the pulmonary tree. The escape of plasma fluid into the alveoli and branches of the bronchial tree presents a problem demanding the application of measures in addition to those already mentioned. The development of a type of pulmonary edema in the acutely injured as a result of "anoxic" anoxia, tracheobronchial obstruction, and increased respiratory effort has been presented. Excessive amounts of intravenous plasma and blood may also be important contributing factors by causing ventricular failure and pulmonary edema.

There is an increased tendency, as evidenced by the recent reports in the medical literature, to use positive pressure oxygen therapy in the treatment of pulmonary edema. The pulmonary edema seen in pneumonia;<sup>8</sup> gas poisoning;<sup>9</sup> and heart disease<sup>10</sup> has been successfully controlled by this method of therapy. The rationale of its use, technics of administration, and the great value of this procedure have been repeatedly shown by Barach, and his associates,<sup>8, 11, 13</sup> in a series of reports. Because we believed that we were dealing with a form of pulmonary edema in these injured patients, positive pressure oxygen seemed advisable. We have used a to-and-fro system containing a soda lime cannister and a rebreathing bag. Positive pressure on the bag was maintained manually, care being taken to avoid excessive pressures. First, we employed all the measures outlined to clear the fluid out of the trachea and bronchi. Edema fluid constantly forming in the alveoli and bronchioles cannot be completely removed by suction. However, the use of suction and the various measures enumerated permit the oxygen to get down to the bronchioles and alveoli. It is the administering of oxygen under positive pressure that serves to keep the bronchioles patent and opposes the hydrostatic pressure of the blood in the capillaries. The extensive work of Barach<sup>13</sup> has shown an increase in the vital capacity with positive pressure oxygen. Positive pressure in the respiratory system must not be raised to 10 cm. of water, as Beecher, and his associates,<sup>12</sup> have demonstrated deleterious effects at this level. They reported a great rise in venous pressure, fall in systolic, diastolic, and mean blood pressures as well as decreased blood flow. However, pressures from 2-6 cm. of water are considered safe by most authors on the subject.<sup>13</sup> In cases that had not been in shock for a long period of time, we have been successful in drying up the wet lungs due to pulmonary transudation and exudation with the use of positive pressure oxygen therapy (Case 3). While severe shock is still present, positive pressure should not be employed since it may seriously impede the return of blood to the right heart.

Some patients do not tolerate the face mask well at first. However, with sufficient encouragement the cooperation of the patient may be obtained. We believe that positive pressure oxygen should be used in these cases with definite pulmonary edema. Theoretically, it also has considerable prophylactic value. The indication for the use of positive pressure oxygen in the early stages of wet lung following trauma cannot be stated at this time. Nevertheless, from our experience, we believe it has a definite place in the treatment of these cases and that further trial of this method of therapy is indicated.

## THE "WET LUNG" IN WAR CASUALTIES

### ILLUSTRATIVE CASE REPORTS

**Case 1.**—A 23-year-old sergeant was wounded in the chest and buttocks by an high explosive fragment in Italy, December 5, 1943. He was admitted to a Semimobile Evacuation Hospital three hours later, dyspneic, with severe chest and abdominal pain. The temperature was 98.6° F., pulse 110, respiration 30, and blood pressure 110/80. Penetrating wounds of the left chest and buttocks were present. There were signs of a large amount of fluid in the left thorax obscuring all other findings, and loud musical wheezes over the right chest anteriorly and posteriorly. A roentgenogram confirmed the presence of fluid on the left (Fig. 1). A small foreign body was seen behind the

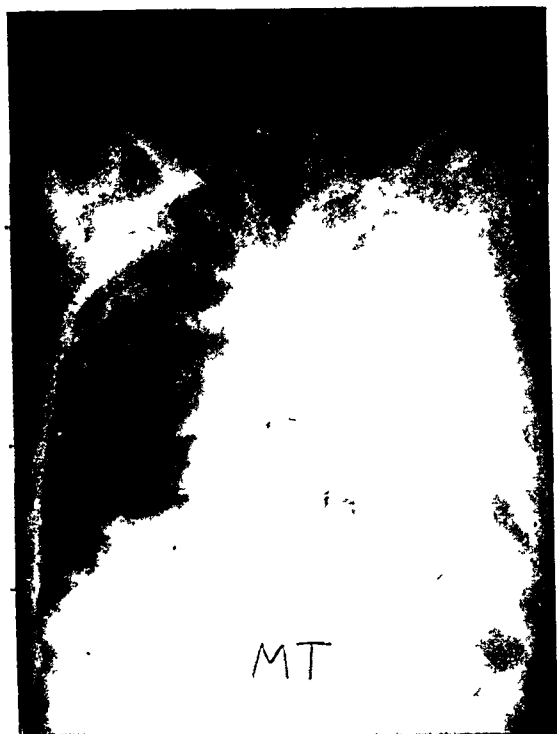


FIG. 1

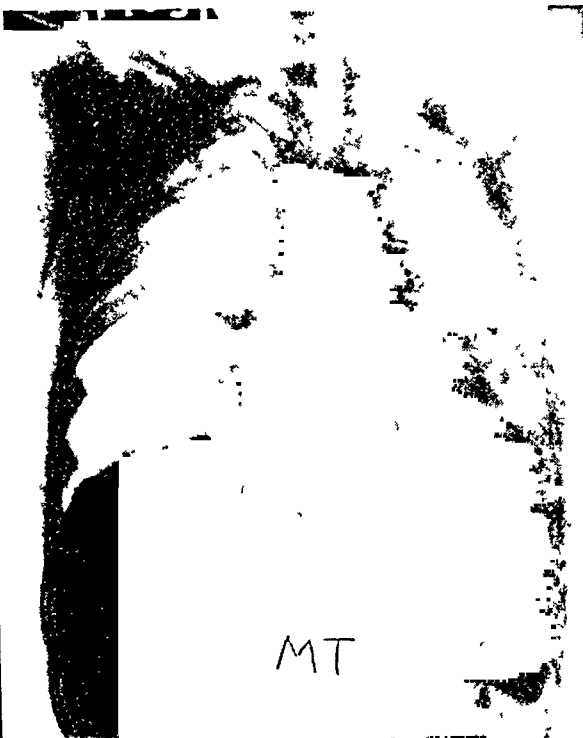


FIG. 2

FIG. 1.—Case 1: Day of injury. Fluid obscures the left chest. Left eighth rib is fractured. There is no roentgenographic evidence of the early stage of wet lung.

FIG. 2.—Case 1: Eight days after injury the lung fields are clear except for signs of residual fluid on the left.

heart and above the left diaphragm, and the left eighth rib was fractured. After  $\frac{1}{4}$  gr. of morphine sulfate and  $\frac{1}{400}$  gr. of atropine sulfate intravenously the chest pain was not sufficiently relieved to permit effective coughing. The blocking of the fifth to tenth intercostal nerves on the left, resulted in the complete relief of pain. He then coughed up a large amount of old and fresh blood mixed with mucus. Following this he breathed deeply and comfortably and on auscultation the lungs sounded dry. Débridement of the chest wall and buttocks was then carried out under pentothal anesthesia. There was no recurrence of severe chest pain and he continued to raise bloody sputum for a week. A total of 2,730 cc. of bloody fluid was removed from the left chest during the first week after injury and the left lung was almost completely expanded (Fig. 2). From then on his course was entirely uneventful.

**COMMENT:** Retention of blood in the bronchial tree from intrapulmonary hemorrhage was, in the main, responsible for the findings of wet lung in this case. Severe chest pain unrelieved by a large dose of morphine prevented adequate cough. Blocking of the intercostal nerves relieved pain, and the patient could raise the blood and mucus accumulated in the bronchial tree.

**Case 2.**—A 24-year-old German prisoner of war received multiple shell fragment wounds in Italy, November 5, 1943. The wounds were dressed and  $\frac{1}{4}$  gr. of morphine sulfate was given at the Clearing Station. One and one-half hours later he was admitted to a Semimobile Evacuation Hospital with dyspnea, but not in shock or severe distress. There were ten wounds of the right chest. The breath sounds were diminished over the right lung due to the presence of fluid. Over the entire left chest anteriorly there were numerous wheezes which persisted after forceful coughing. Spasm, tenderness, and rebound tenderness were noted in the right upper quadrant of the abdomen. Fluoroscopy showed a 6-mm. metallic foreign body in the right posterior inferior mediastinum and fluid in the right chest. There were several smaller foreign bodies apparently in the abdominal and thoracic wall. Exploratory celiotomy was indicated to rule out intra-abdominal injury. In spite of the fact that morphine had controlled the chest pain sufficiently to permit hard coughing, the early signs of wet lung persisted. We did not wish to proceed with the operation without attempting to dry up the bronchial tree first. Intercostal nerve block of the fourth and 12th nerves on the right side was performed. Shortly after this the wheezing disappeared and he raised mucoid sputum. The lungs now sounded dry. Exploratory celiotomy, removal of abdominal wall foreign bodies, and débridement of chest wall wounds were performed under ether-oxygen anesthesia. The patient's course from then on was uneventful and there was no recurrence of the wet lung.

**COMMENT:** Multiple chest and abdominal wall wounds were present without evidence of shock, pulmonary hemorrhage, or infection. The morphine sulfate alleviated the chest pain sufficiently to allow the patient to cough forcefully but early signs of wet lung persisted. Following the blocking of intercostal nerves supplying the injured part of the chest, the patient raised some mucoid sputum and the wheezes dramatically disappeared. This appears to be evidence that the intercostal nerve block resulted in a cessation of bronchial spasm and excess mucous secretion.

**Case 3.**—A 21-year-old sergeant received multiple wounds in Italy, January 23, 1944. He arrived in a Field Hospital three hours after injury in severe shock, with a pulse rate of 140. The blood pressure could not be obtained. A sucking wound of the left chest and penetrating wounds of the right chest, thigh, forearm, hand, and cheek were present. Signs of fluid were elicited in the left chest. The breath sounds were diminished on the right. He was in severe pain, not having had any narcotic since being wounded. After placing an occlusive dressing on the "sucking wound"  $\frac{1}{2}$  gr. of morphine sulfate was given intravenously. The dose was repeated in a short time with relief of the pain. Following the administration of two units of plasma and 500 cc. of blood, the blood pressure was 104/80, and the pulse was 132. He was raising small amounts of bloody sputum. Two hours later his condition became critical. When we were called to see him, he was comatose, cyanotic, with audible tracheal râles and a weak thready pulse. Catheter suction was performed at once and large amounts of yellow frothy sputum was aspirated. His response was dramatic. Consciousness returned. Pulse and color improved. Suction was repeated every 20 or 30 minutes, 100 per cent oxygen being administered through the catheter that was left in place in the trachea in between aspirations. The catheter was kept in the trachea for a period of eight hours, during which time his condition steadily improved. A chest roentgenogram taken at this time (Fig. 3) showed fluid in the left chest and foreign bodies in both lung fields. The catheter had slipped into the right main bronchus. Since the bronchial tree was dry, the catheter was removed. A blood transfusion of 500 cc. and one unit of plasma were given, followed by the aspiration of 100 cc. of air and 200 cc. of bloody fluid from the left chest. Two hours later (17 hours after admission) his blood pressure

was 108/74, and he was judged to be in suitable condition for surgery. One-eighth grain or morphine sulfate and  $\frac{1}{100}$  of atropine sulfate were given intravenously, as preoperative medication, prior to the administration of ether and oxygen intratracheally. Bronchoscopy was performed before surgery was started, with the aspiration of considerable amounts of bloody sputum from both main bronchi. No evidence of trauma to the larynx or tracheal mucosa from the tracheal catheter was seen. The sucking wound of the left chest was débrided. The internal mammary vessels were found to be lacerated. Although not bleeding, they were ligated. A laceration of the upper lobe of the left lung was sutured with fine silk. Several small metallic foreign bodies present in the pericardium

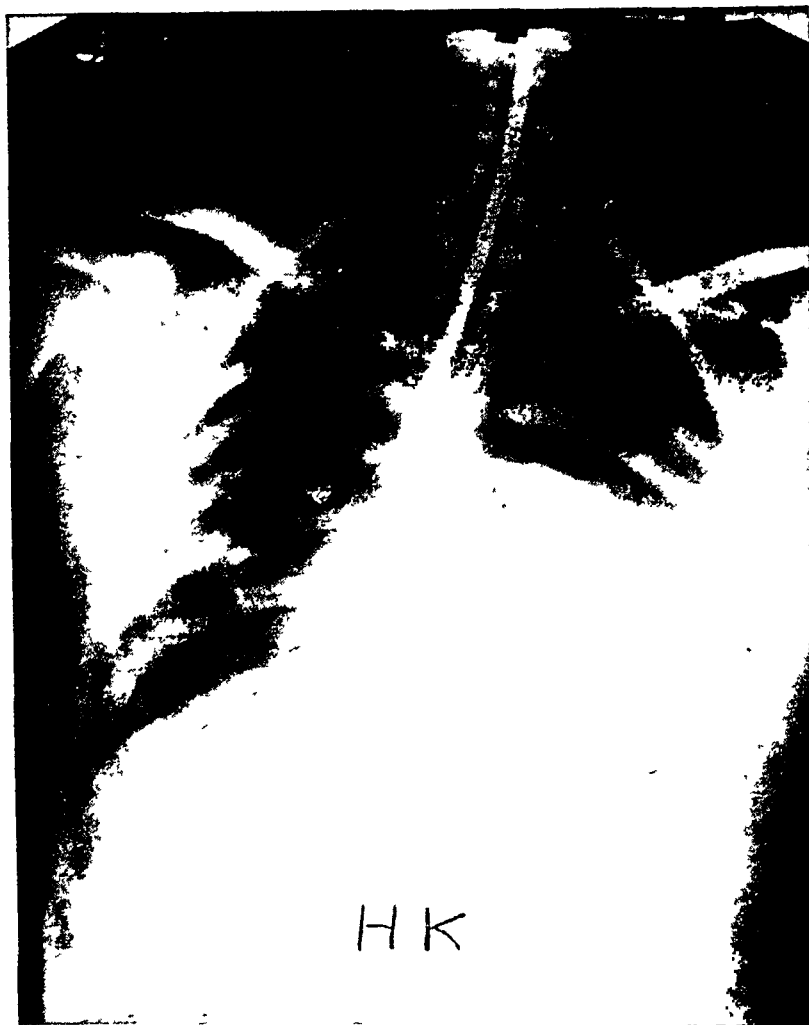


FIG. 3.—Case 3: Day of injury. Fluid obscures lower three-fifths of the left chest. Foreign bodies and some mottling of the right lung field are present. Catheter is seen in upper portion of the right stem bronchus.

were removed. An attempt to remove the foreign body in the lower lobe of the lung was not deemed advisable. The chest wall was closed in layers leaving the skin open. An intercostal drainage tube was used. A foreign body was removed from the right chest wall, but no attempt was made to remove the foreign body in the right lung. During the performance of the thoracic surgery another surgical team débrided the other wounds. One unit of plasma and 500 cc. of blood were administered during the operation. Post-operative bronchoscopy was performed with the aspiration of a moderate amount of bloody mucus from both stem bronchi. His immediate postoperative condition was satisfactory.

On the day after operation he became disoriented, which condition we attributed to

cerebral anoxia, in spite of the fact that oxygen was administered by nasal catheter. Although his cough was productive of thin yellow fluid, the pulmonary tree seemed to be filling up with moisture, and his condition rapidly became critical.

The temperature was 99.4° F., the pulse was 150, and the respirations were 48 per minute. Following tracheobronchial catheter aspiration his breathing was less noisy and the tracheal bronchi and coarse bronchial râles disappeared. However, medium and fine râles could be heard with the stethoscope diffusely over all lobes of the lungs. It appeared that fluid was being formed in the peripheral portions of the lungs more rapidly than it could be removed. The clinical picture was similar to that seen in pulmonary edema accompanying heart disease, gas poisoning, and other conditions. Because we were



FIG. 4

FIG. 4.—Case 3: Second day after injury. There is mottling of both lung fields and marked subcutaneous emphysema is present.

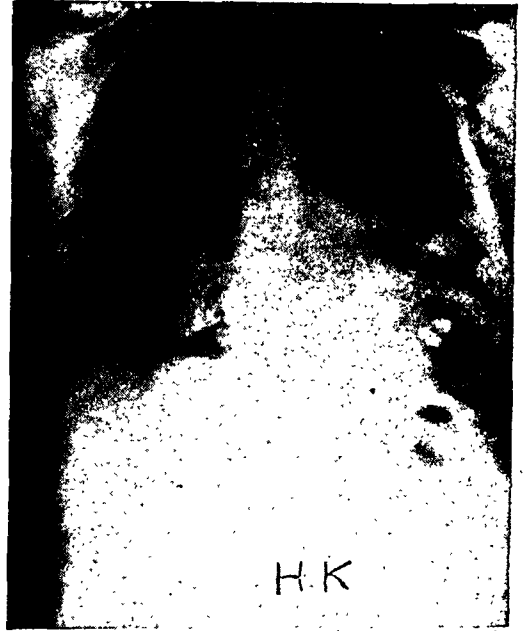


FIG. 5

FIG. 5.—Case 3: Fourteen days after injury. There is some residual mottling of the left lung. Subcutaneous emphysema persists.

convinced that we were dealing with true pulmonary edema positive pressure oxygen (not exceeding 6 cm. of water) was administered with a to-and-fro system containing a soda lime cannister. After about 15 minutes time there was a definite improvement in the patient with a disappearance of the cyanosis. The râles now disappeared except for a few fine râles at the bases and the pulse rate fell to 120. The respirations were less labored and decreased to 32 per minute. After 15 minutes more the positive pressure oxygen was stopped and oxygen was administered by the B. L. B. mask. During the next 24 hours he had two additional attacks of pulmonary edema resembling the one cited. In both of these instances the administration of oxygen under mild positive pressure resulted in a "drying up" of the lungs, a decrease in pulse and respirations, and a dramatic improvement in the patient's condition in a similar manner.

COMMENT: This case is of the utmost interest as an example of the therapeutic problem presented by wet lung occurring in a patient with multiple chest and other wounds. After his arrival at the field hospital tracheobronchial catheter aspiration was performed and oxygen administered for eight hours intratracheally in addition to the cautious fluid replacement therapy. Through the continued use of these technic the patient was brought out of

shock and made a suitable candidate for closure of his sucking wound and débridement of the other wounds. Bronchoscopy performed just before and after operation aided in the maintenance of an air-way during operation and helped his immediate postoperative courses. Later, on three occasions what appeared to be true pulmonary edema developed. The administration of oxygen under mild positive pressure in each instance resulted in "drying up" of the lungs, decrease in pulse and respiration, disappearance of the cyanosis, and marked general improvement. The exact pathologic physiology responsible for the development of pulmonary edema in this case is not completely understood. Anoxia due to severe trauma to both lungs and tracheal obstruction for mucus and blood were probable important factors. We do feel certain, however, that it was the continued use of the procedures mentioned above that was responsible for the successful outcome of this case.

**Case 4.**—A 27-year-old lieutenant sustained a "sucking" chest wound, July 19, 1943. This wound was treated by an occlusive dressing and within 24 hours a primary pleural closure was done, leaving the skin unsutured. He expectorated small amounts of pure blood for three days. The patient was admitted to the thoracic surgery center five days after injury. He was moderately dyspneic on exertion, comfortable at rest. He had a wet cough, productive of only small amounts of blood-tinged, mucoid sputum. There were a few coarse râles parasternally on the right. Roentgenograms on the day after admission showed a right-sided hydropneumothorax without cardiac shift (Fig. 6). There were comminuted fractures of the fifth and sixth ribs posteriorly. On the day after admission and the following day, 360 cc. and 390 cc. of old pleural blood and air, respectively, were removed from the right chest. Following each aspiration, highly negative intrapleural pressure prevented the continuance of the procedure. The wet cough continued and did not improve in spite of the administration of CO<sub>2</sub> and frequent changes in position. Roentgenograms on the following day showed a minimal residual hemopneumothorax, expanded upper lobe and atelectasis of the right middle and lower lobes (Fig. 7). Bronchoscopy was, therefore, indicated. Bronchoscopic aspiration was productive of large amounts of blood clots and mucus, which had partially formed bronchial and bronchiolar casts. The patient's cough became loose, remained productive for four days following aspiration, then ceased altogether. Roentgenograms taken 18 hours following bronchoscopy showed almost complete re-aeration of the right middle and lower lobes (Fig. 8). In eight days, the right lung had completely expanded and was rapidly approaching normal (Fig. 9).

**COMMENT:** The roentgenographic evidence of atelectasis was obscured by the hemothorax. The following points in the history should, however, make the diagnosis almost certain without roentgenographic proof: Continued wet cough with inadequate expectoration; extensive hemopneumothorax without cardiac shift; and the development of severe negative pressure symptoms following aspiration of relatively small amounts of fluid. The aspiration of old blood clots and mucus by bronchoscopy resulted in the prompt reestablishment of the air-way and reexpansion of the lung. Earlier attention to the patient's wet lung according to methods outlined in this communication, might have obviated the occurrence of this complication; atelectasis.

**DISCUSSION:** In presenting the clinical problem of wet lung following trauma we have discussed under this term everything from the beginning moisture in the pulmonary tree to the full-blown pulmonary edema. Atelecta-

FIG. 6

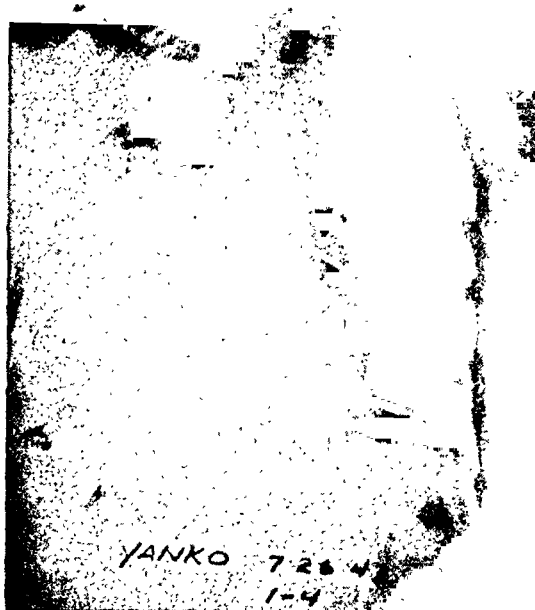


FIG. 7



FIG. 8

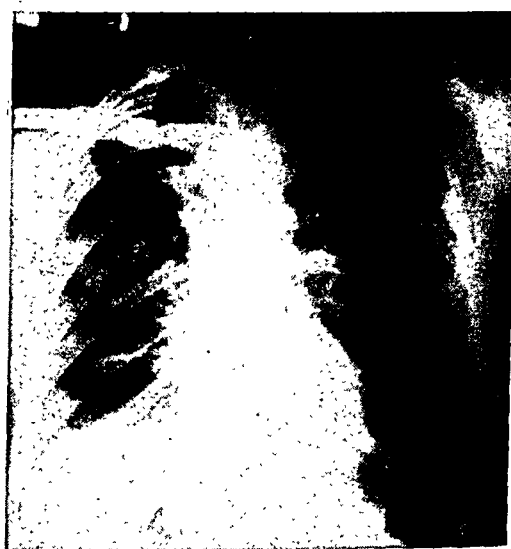


FIG. 9

FIG. 6.—Case 4: Admission roentgenogram, five days after injury. Right hydro-pneumothorax, without cardiac shift, is present.

FIG. 7.—Case 4: Day after admission. Seven hundred fifty cubic centimeters of blood and air have been removed from the right chest. Although the upper lobe is expanded, there is persistent atelectasis of the right middle and lower lobe.

FIG. 8.—Case 4: Immediately following bronchoscopy. The middle and lower lobes are expanding.

FIG. 9.—Case 4: Four days after bronchoscopy. The right lung is expanded.

sis and pneumonia are emphasized as the important sequelae. Some will argue that this term might better be reserved for only the fully developed picture of pulmonary edema seen in the acutely injured. We have purposely included the milder states for we wish to emphasize the importance of relatively small amounts of fluid in producing obstruction to the pulmonary air-way. The retention of fluid substances in the bronchial tree may initiate a set of circumstances that greatly alter the pulmonary physiology. Unless this train of events is broken up by the measures we have discussed, serious complications set in. On the other hand, once the patient is successful in keeping his pulmonary tree free of fluid material, he is usually well on the way to recovery.

We are impressed more and more as time goes on with the important rôle that anoxia plays in increasing the degree of shock in acutely injured patients. The therapeutic measures advocated, in the main, are those which improve the respiratory air-way and provide adequate oxygen supply to the pulmonary capillaries, even though it means "forcing" the oxygen into the alveoli under mild positive pressure. In our experience in the Forward Hospitals, edema of the lungs appeared to be the most significant finding at autopsy in patients who survived the initial shock but later died of their chest injury.

There may well be other mechanisms to disturb the pulmonary physiology in these cases in addition to the ones presented. Neither time nor the facilities have been present for an adequate study of this problem in the forward surgical installations.

Elaborate investigation of the cardiopulmonary functions of these patients would be desirable, supplemented with experimentation on laboratory animals. Although the pathology is not completely understood, we do know from our study of this large series of traumatic cases that this clinical state presents one of the most serious problems confronting the surgeon in the forward installations.

#### CONCLUSIONS

1. The problem of the wet lung following trauma has been presented.
2. In the severely wounded, there are many factors which favor the accumulation and persistence of fluid in the pulmonary tree.
3. The altered physiology resulting from the retention of fluid in the respiratory tract is discussed.
4. In restoring the normal physiology, the therapeutic measures that are most important are intercostal nerve block, tracheobronchial aspiration either with the catheter or the bronchoscope, and positive pressure oxygen therapy.
5. Illustrative case reports are presented.
6. The treatment of wet lung is one of the most challenging problems facing the surgeon handling the severely wounded.

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## PENETRATING WOUNDS OF THE CHEST

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A TOTAL of 402 patients with penetrating or perforating wounds of the chest were treated in a General Hospital during the campaign in Italy from November, 1943, to September, 1944, and in Eastern France from November, 1944, to February, 1945. It is the purpose of this paper to discuss the problems encountered, together with such conclusions as can be drawn from our observations. During the same period of time an equally large number of patients with chest wall injuries, pulmonary contusions and blast injuries of the lung had been treated. Many of these have had associated hemothorax, but have not been included in this study because the wounds had not penetrated the pleural cavity.

Final end-results cannot be discussed at this time for several reasons. The expression "returned to duty" cannot be accepted as an end-result until it can be shown that such patient remained at full duty, or even limited duty. It has been our experience as well as that of others that some patients have been returned to their outfits designated as fit for duty and have been returned after short periods of time to other hospitals for reclassification on the basis of pain, dyspnea, *etc.* A complete follow-up study will be responsible only after the war, and may well reveal flaws in our conception of the fate of the posttraumatic chest.

Our patients were received for the most part from Evacuation or Field Hospitals. A few were admitted directly following accidents occurring in the vicinity; and another group was admitted from the Front without preliminary treatment in Forward Hospitals. This occurred during the early days of the Anzio and Southern France invasions.

We were thus able to follow with considerable interest the transition in Forward chest surgery with its increasing emphasis on conservatism. Certainly, patients are being received at present with pulmonary injuries and retained foreign bodies who would have been treated by formal thoracotomy at Forward installations a year ago. It is our feeling that this conservatism is more than adequately justified by results. We have been favorably impressed by the condition on arrival of patients who have had no more elaborate treatment than débridement and aspiration, or débridement and closure of sucking wounds. As will be shown later, many of these patients require no further formal intrapleural surgical treatment.

It is perhaps in order to discuss the most favorable location of hospitals for definitive chest surgery. We feel that this is best carried out at the nearest hospital, where an uninterrupted convalescence can be expected. If military conditions would permit patients to be held for 30 to 60 days at the Evacuation or Field Hospitals, these would be ideal locations for all definitive surgery. As this is obviously impossible the next best solution is the Forward General Hospital, with the least possible delay *en route*. The importance of minimal

delay in travel will be shown in detail in the discussion of thoracentesis and blood transfusion. This point of view was brought forward by Nicholson and Scadding,<sup>1</sup> and further by Churchill<sup>2</sup> in his presentation of the surgical problems encountered during the Italian campaign.

### HEMOTHORAX

Hemothorax is by far the commonest single complication of penetrating wounds of the chest, occurring 326 times in our series of 402 cases. These represent 78.5 per cent of the total number of cases studied. One hundred and twenty of these hemothoraces were complicated by pneumothorax.

Hemothorax usually occurs immediately as a result of wounding, but the delayed appearance of hemothorax has been observed by the authors and will be discussed below. Bleeding is usually from a lacerated lung or intercostal vessels. We have never seen bleeding from large pulmonary or mediastinal vessels since they rarely arrive alive even at Field or Evacuation Hospitals.

We have not aspirated small, asymptomatic hemothoraces, and have found that almost all of these will disappear in a short time if early ambulatory activity is encouraged. If a hemothorax is small and complicated by fever, dyspnea or pain in the chest, aspiration is carried out for both diagnostic and therapeutic reasons. Many times pain can be relieved by the removal of a small amount of blood.

The large hemothorax must be aspirated early and frequently in order to obtain satisfactory results. The prime purpose of aspiration is to obliterate abnormal pleural space and allow the lung to reexpand. This is essential if the pulmonary dynamics are to be restored to normal.

The Baxter transfusion vacuum bottle and valve are used for aspiration (Fig. 1). We have found the use of this apparatus to be a simple, air-tight and sterile method for the removal of chest fluid. It allows the removal of 600 cc. of blood or air at one time, and the rate of removal can be easily adjusted by the use of the valve. The interspace of choice for thoracentesis is determined by roentgenographic and physical signs, and is usually at the lowest level of the fluid. Percussion note is the most reliable single sign according to our experience. Absence of breath sounds may be the result of splinting of the chest and decreased respiratory excursion and cannot always be interpreted as an indication of fluid. It has also been noted in several of our cases that breath sounds may be heard through an empyema or hemothorax. D'Abreu<sup>3</sup> mentions this phenomenon.

The removal of 600 cc. at one time has been practiced and we have rarely exceeded this amount. Aspiration of larger quantities result in untoward symptoms such as cough, pain in the chest and feeling of faintness. When these symptoms appeared aspiration was discontinued immediately. We have preferred to remove 600 cc. amounts frequently rather than larger amounts at one time in order to avoid these alarming symptoms.

The injection of air into the pleural space following thoracentesis was not used in any of our cases. We do not share the opinion that air replacement

## PENETRATING WOUNDS OF CHEST

will prevent further bleeding from the expanded lung. That bleeding recurs after aspiration is conjecture and is not validated by proof. We have found the opposite to be true by studying the hematocrit, hemoglobin and plasma protein of hemothorax fluid. A sample of the aspirated fluid was studied by the Van Slyke copper sulfate method after each aspiration and it was found that in no instance was there evidence of increased bleeding. In fact, in all patients, aspirated more than once, there was a definite progressive decrease

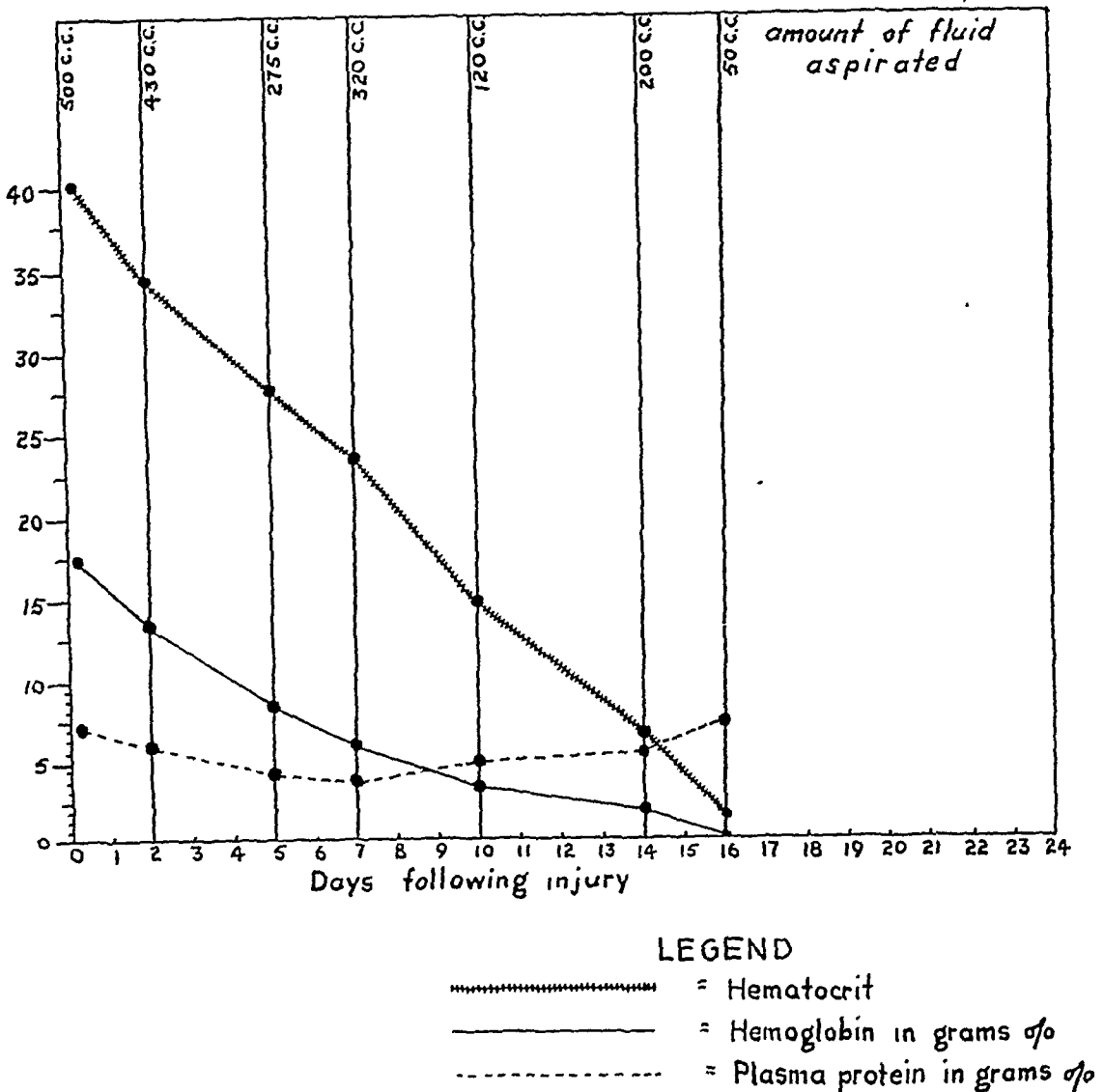


CHART I.—Showing changes in hemothorax fluid in a patient aspirated a few hours after receiving a penetrating chest wound.

in the hematocrit and hemoglobin readings of the fluid. The plasma protein usually showed a terminal rise and this fact coupled with the fact that the hematocrit and hemoglobin decreased steadily is presented as evidence that increase in hemothorax fluid is due to exudation and not recurrence of bleeding. Exudation may be the result of pleuritis. Chart I shows the changes in hemothorax fluid in a patient received a few hours after injury and is typical of the curves obtained in the other cases studied.

It has been stated that obliteration of abnormal pleural space is one of the primary purposes of aspiration and it is logical that air replacement defeats this purpose. Air injected into the pleural space tends to rise, thereby compressing the apex of the lung. If empyema is inevitable it will be total if the apex is collapsed; and the difficulty of healing a total empyema is well appreciated.

The delayed appearance of hemothorax was noted in several instances, and was usually in patients with small, perforating, bullet wounds of the chest. These patients were evacuated from Forward installations with apparently dry pleural spaces and shortly after arrival at this hospital the presence of hemothorax was evident. This might be explained on the basis of late liquefaction of pleural blood clots with subsequent exudation. Clot liquefaction may open previously sealed bronchopleural fistulae and result in tension pneumothorax. Four patients arrived at this hospital with severe tension pneumothorax which had its onset in transit. Many more patients arrived, complaining of dyspnea and pain which were not present before evacuation to this hospital. These patients stated that they were comfortable before they were transported and that their alarming symptoms appeared during transportation.

Elevation of temperature in patients with hemothorax presented an interesting problem. Eighty-seven patients showed a daily temperature rise of over 100° F. for more than five days and some for as long as three weeks. None of these patients developed empyema, nor did smear and culture studies of their hemothorax fluid show bacterial contamination. Their fever could not be attributed to concomitant wounds. We found that daily aspiration, with subsequent disappearance of hemothorax, almost always brought about a decrease in the temperature to normal.

Clotted hemothorax has been the subject of much controversy among thoracic surgeons in World War II. A distinction must be made between an inaspirable hemothorax and a clotted hemothorax. The clotted hemothorax obviously is not aspirable, but it does not necessarily follow that the inaspirable hemothorax is clotted. The traumatized chest wall and lung are prone to form many bands and points of adherence which may make aspiration difficult or even impossible.

It has been our practice to treat uninfected inaspirable hemothorax conservatively, by repeated attempts at aspiration, blood replacement, early ambulatory activity and breathing exercises. If at the end of five weeks there was no evidence of expansion of the lung and disappearance of the blood, a thoracotomy and decortication were done. There were 41 cases considered inaspirable and of these only 11 required decortication after five weeks of conservative therapy. The remaining 30 patients showed adequate reexpansion and disappearance of fluid at the end of this five-week period and no surgical treatment was necessary. Five patients with total empyema were decorticated.

The above observations and facts have convinced us that hemothorax, the commonest complication of penetrating chest wounds, is best treated early

and diligently. In order to carry out these aims, these patients should be retained in General Hospitals close to Field and Evacuation Hospitals, and not passed through a long chain of evacuation to Base sections.

#### FOREIGN BODIES

Seventy patients with intrathoracic foreign bodies were received. These were removed in 25 instances. In 19, operation was performed primarily for the removal of foreign bodies and in the remainder removal was incidental to other procedures. The rôle of the retained foreign body in the causation of intrapulmonary or intrapleural suppuration has never been thoroughly settled. Academically, it would seem that retained foreign bodies predispose to infection, and it is perhaps fair to say that they do act as a *locus minoris resistentiae*. We do know, however, that a large proportion of these remain asymptomatic for the life time of the individual. It is equally true that a small proportion of them result in early suppuration, and a still smaller proportion is responsible for hemoptysis or suppuration in later years. There are no statistics available to indicate the frequency of these as late complications and a careful post-war follow-up could be very useful in establishing a working rule for the therapy of retained foreign bodies. It is our impression that in the absence of complications the present trend is toward conservatism.

We feel that the size and surface area, together with concomitant presence of cloth, débris, *etc.*, are the most important factors in the production of infection. This presupposes that all foreign bodies are unsterile. It has been stated that the irregular foreign body is a more frequent offender than the smooth one, which may be true. Certainly, the irregular fragment has a much greater surface area upon which contaminants may be carried. It has been further stated that bone fragments are likely to be more harmful than metallic fragments, but this has not been our experience.

In the absence of known suppuration it is our policy to remove all large foreign bodies (2 cm. and over); those projecting into the pleural cavity or diaphragm; those within or adjacent to the pericardium, and all others which appeared to be the cause of persistent symptoms of cough or pain. We have not encountered large mediastinal foreign bodies but agree that their removal is indicated when feasible.

It has also been our custom to remove such foreign bodies as are easily available during the performance of other intrathoracic procedures. Obviously, all foreign bodies known to be the source of sepsis should be removed.

Total cases with intrathoracic foreign bodies:

Foreign bodies—total cases.....	70
Removal in this hospital.....	25
Removal as primary procedure.....	19
Removal incidental to other procedures.....	6

In one case a pulmonary abscess, demonstrable roentgenographically, had formed about a foreign body. In four cases minute abscesses otherwise unsuspected have been found about foreign bodies during removal. It was not

uncommon to find cloth and débris with the foreign body without evidence of suppuration. There was no incidence of empyema except for one small basal empyema which followed decortication for total putrid empyema with retained intrapleural foreign body. A giant lung abscess which formed about a large foreign body with adherent clothing was drained in one stage without difficulty or complication.

Location of intrathoracic foreign bodies:

Intrapulmonary.....	15
Intrapleural.....	8
Intradiaphragmatic.....	2

#### ABDOMINOTHORACIC INJURIES

There were 96 cases of abdominothoracic injury, 89 of which had been operated upon at Forward installations. Seven received their initial surgery in this hospital. Three of this latter group demonstrate the ease in which this complication may be overlooked. In these three the existence of the thoracic injury had been recognized, but for one reason or another the more serious complication had been overlooked. Clinical study of the probable track of the missile, together with roentgenography, should make the diagnosis possible in the absence of more obvious signs. In one of our cases, with an entrance wound in the right scapula and an exit wound in the right groin, previous examiners had considered both wounds to be individual entrance wounds. In another instance the thoracic wound was appreciated, but the presence of a large missile in the pelvis was overlooked. Fortunately, no serious complications resulted from the delayed (48-72-hour) operative treatment.

In 23 cases, 22 left-sided, the operative approach was transdiaphragmatic through a thoracotomy incision. This was highly satisfactory, though in two cases formal celiotomy was added for further exploration. Colostomy, of course, required an abdominal incision. Wounds of the right side were usually treated by thoracotomy and celiotomy.

The operative procedures were as follows:

Thoracoceliotomy.....	23
(In addition there were 2 supplemental celiotomies)	
Thoracotomy.....	38
Thoracotomy and celiotomy.....	14
Celiotomy (alone).....	11
Celiotomy plus débridement of chest wall.....	8
Débridement.....	8
No treatment.....	2

We have previously discussed the advantage of the transdiaphragmatic thoracoceliotomy.<sup>4</sup> As our experience has increased, we have become further convinced that this approach is ideal for splenectomy. Nephrectomy, when indicated, may be performed with ease through the diaphragm, as well as suture of lacerations or perforations of the stomach.

## PENETRATING WOUNDS OF CHEST

The incidence of injury to intra-abdominal organs is shown in the accompanying table. Frequently two or more organs were injured by the same missile. The diaphragm alone was injured in 12 instances.

Liver.....	52
Spleen.....	15
Kidney.....	12
Stomach.....	12
Small intestine.....	8
Large intestine.....	7
Pancreas.....	3

Complications of thoracoceliotomy were fewer than might be expected. No evidence of postoperative diaphragmatic hernia was noted, though its possible occurrence as a late complication cannot be disregarded. Complications of abdominothoracic injuries were as follows:

Empyema.....	5
Empyema and lung abscess.....	1
Liver abscess.....	1
Liver and lung abscess ("collar-button" type).....	1
Osteomyelitis of rib ends.....	2
Intestinal obstruction.....	1

There was one fatality due to gradual failure of kidney function. This case will be discussed later.

### CONTUSION

Simple contusion of the lung with no demonstrable hemothorax was present in 45 patients, or 11.25 per cent; of these, nine developed pneumonia, with clinical and roentgenographic signs. They cleared rather rapidly under sulfadiazine and supportive therapy. Simple contusion usually cleared within 10-20 days following injury. Hemoptysis occurred occasionally, but was never copious or of long duration in our cases.

### LUNG ABSCESS

Lung abscess occurred three times in the 402 cases, once around a large retained shell fragment and once in a patient with a large empyema and pneumonia of the underlying lung. The third lung abscess involved most of the lower right lobe and communicated with a liver abscess through a diaphragmatic fistula. These patients all recovered following surgical drainage. Lung abscess has been discussed elsewhere by the authors.<sup>5</sup>

### WOUNDS OF THE PERICARDIUM AND HEART

A total of 12 pericardial or cardiac wounds were encountered. Three patients had fragments removed from the ventricular musculature, one had a fragment removed from the pericardial space between the pulmonary artery and aorta. These procedures were done at Forward Hospitals. The remaining eight patients had penetrating or lacerating wounds of the pericardium with pericardial effusion varying from slight to severe. Three patients were



evacuated with small foreign bodies retained within the pericardial sac. One of these still had signs of pericarditis and was febrile. This patient was the only one of the group of 12 who had any febrile reaction or evidence of pericarditis when evacuated. One patient with tamponade could not be aspirated by the conventional method. The sixth left costal cartilage was resected through a precordial incision, and the pericardial sac was drained and 5,000 units of penicillin instilled into the pericardial cavity; recovery was good. Our conservative therapy of pericarditis with effusion consisted of oxygen, when indicated, and full doses of penicillin and sulfadiazine. Both of these drugs were used because of the uncertainty of the type of infecting organism, if any. There were no deaths.

#### EMPHYEMA

In the 402 cases discussed, empyema was encountered 34 times, or 8.4 per cent of the total. Seventeen of these patients had thoracotomies done at Forward Hospitals, two had thoracotomies done at this hospital, 15 developed empyema without a preceding thoracotomy. Ten of the 34 patients had established empyema on admission to the hospital. Eight of these ten had had formal thoracotomies at Forward Hospitals. The above figures tend to indicate that empyema is slightly more common following early formal intrapleural surgery. This difference may be dismissed by the fact that patients requiring thoracotomy Forward usually had more severe chest wounds.

Empyema, if small and basal, offers no great problem in treatment, and if drained early and adequately almost always heals. The distressing problem is the total empyema with apical collapse. This is the type that requires decortication and may result in chronic empyema. Decortication for total empyema was necessary in only five of our cases. The remainder were treated by rib resection. We have favored the use of the Leahy tube (Fig. 2) for empyema drainage. It affords a means for maintaining adequate placement of the tube flush to the chest wall and also allows irrigation of the empyema cavity without disconnecting the under-water drainage which we have used almost routinely. The muscle and skin can be closed in layers with interrupted silk around this tube to guarantee an air- and water-tight drainage system. We believe that water-sealed closed drainage with a large tube (Fig. 3) brings about a more rapid obliteration of the empyema cavity. The negative pressure exerted is favorable for expansion of the underlying lung.

If empyema is inevitable it is best to strive for a small localized one, and early and frequent aspiration of the hemothorax or hydrothorax is strongly recommended to attain this result. Everything must be done to bring about early and rapid expansion of the lung and the following points are emphasized: diligent maintenance of normal blood level; early ambulatory activity and early and frequent aspiration.

#### PNEUMONIA

Pneumonia has been a troublesome but not severe complication in patients with penetrating chest wounds. It was recognized by the usual roentgeno-

graphic and clinical signs of consolidation. The diagnosis of pneumonia was made in 38 of our cases and, interestingly enough, 20 of these had their consolidation in the uninjured lung. This may be explained by the fact that generalized thoracic splinting occurs following chest injury and that patients tend to lie on their uninjured side, thereby decreasing the pulmonary excursion. The hypotaxis and relative pulmonary inactivity predisposes to atelectasis and pneumonia. Twelve of these patients developed pneumonia while receiving penicillin. Full doses of sulfadiazine were used in preference to penicillin. One patient developed a small empyema; and one had a small pleural effusion which cleared rapidly after aspiration. One developed a lung abscess and is discussed under that subject. There were no deaths due to pneumonia.

#### GENERAL CARE

In the general care of these patients emphasis is placed upon blood replacement, nutrition, and prevention and control of invasive infection. It is logical to assume that a patient with a large hemothorax has lost a large amount of blood and suffers from anemia just as severely as a patient who has lost 1,000 cc. of blood externally. It is, therefore, extremely important to correct the anemia due to hemothorax with adequate whole blood transfusions. For example, in one patient, who was received one hour following a perforating gunshot wound of the chest, the copper sulfate studies of the aspirated chest fluid revealed an hematocrit of 48; hemoglobin of 16.8 Gm.; and plasma protein, 6.8 Gm. The venous blood taken at the same time revealed an hematocrit of 28; hemoglobin of 9.2 Gm.; and plasma protein, 6.5 Gm. Six hundred cubic centimeters of blood were removed at preoperative aspiration and 800 cc. were removed at the time of débridement and closure of the sucking wound. This patient was aspirated at daily intervals following the initial surgery, and between 200 and 500 cc. of blood were removed daily for four days. It is obvious that this patient required multiple transfusions in order to maintain normal blood volume and content. In order to make a patient ambulatory at an early date the blood must be maintained at a normal level.

Early ambulatory activity is essential and valuable because it promotes general muscular exercise and increased respiratory excursion. In order to bring about complete expansion of a totally or partially collapsed lung, a complete respiratory excursion is important. Deep breathing is most easily achieved by ambulation.

Anemia due to blood loss in this series of cases was rather marked, as shown by the following figures. Many of these patients had associated extremity wounds which contributed to the degree of anemia noted. The Van Slyke copper sulfate method for determination of hematocrit, hemoglobin and plasma protein was used. Patients with an hematocrit of 40, or over, were not considered to be suffering from anemia of blood loss. An hematocrit of 36 to 40 was considered evidence of slight anemia; an hematocrit of 31 to 36, moderate anemia; and an hematocrit below 30, severe anemia. The percentages in the various groups are listed:

Hematocrit	Percentage	Grade
Over 40	17.2	No anemia
36-40	41.6	Slight anemia
31-36	24.6	Moderate anemia
26-30	12.2	Severe anemia
21-26	3.9	
15-20	0.5	

These figures show that 82.8 per cent of the patients admitted had anemia of some degree which required transfusion. In the group classified as slight anemia, 500 to 1,000 cc. of whole blood were usually sufficient to restore the level to normal and maintain this level unless there was complicating sepsis or increasing hemothorax. In the more anemic group, transfusions of 1,000 cc. of whole blood repeated as often as necessary were given. We have been impressed by the clinical improvement in patients when the hematocrit was maintained at the normal level.

The rôle of whole blood in combating infection is well-accepted and should not be neglected. Even when hemothorax fluid shows a marked decrease in hematocrit and hemoglobin, the plasma protein content is usually sufficient to indicate a rather marked loss of protein from the body tissues or blood stream. We believe that this fact has been overlooked, and have emphasized the necessity of high protein diet and plasma transfusions in order to overcome this protein loss. For example, a patient with a chest wound of three weeks duration was aspirated, and 600 cc. of amber fluid was removed from the right pleural space. The hematocrit was 0, hemoglobin 0, and plasma protein 8.8 Gm. This corresponds to the loss of 52.8 Gm. of protein and must, of necessity, be replaced if adequate healing is to be expected. If the patient's general condition and appetite permits, the most desirable way to provide this protein is through his diet. If this is not possible plasma or whole blood transfusions should be used. The rôle of vitamins in wound healing and general nutrition needs no discussion, and may be dismissed by saying that all these patients received an adequate daily dose of polyvitamins.

Penicillin in doses of 25,000 units intramuscularly, every three hours, was given to all patients on admission and continued until there was no evidence of infection or until no effect was obtained clinically. The continued administration of penicillin was necessary only in a small number of cases. It was interesting to note that routine administration of penicillin did not prevent the complication of atelectasis and pneumonia in patients confined to bed. Twelve patients developed clinical and roentgenographic evidence of pneumonia in the injured or uninjured side while receiving penicillin. In these cases sulfadiazine was given along with penicillin and the pneumonia subsided rather rapidly. Patients with injuries of the chest wall and lung tend to lie on their uninjured side for reasons of comfort. This was discouraged and the patients were kept in a sitting position or on their injured side with adequate padding. When the uninjured side of the chest is dependent there is partial splinting of the chest wall, which prevents complete respiratory excursion, increases the anoxia and may result in atelectasis and pneumonia.

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The importance of maintaining mobility of the injured side of the chest was carefully explained to the patients, and they were instructed in deep breathing exercises with emphasis on conscious use of the intercostal muscles and the diaphragm. We believe that this prevents many of the fused chests and deformities which were formerly seen in severe chest wounds. Oxygen was used when cyanosis was evident. Usually the nasal catheter was used

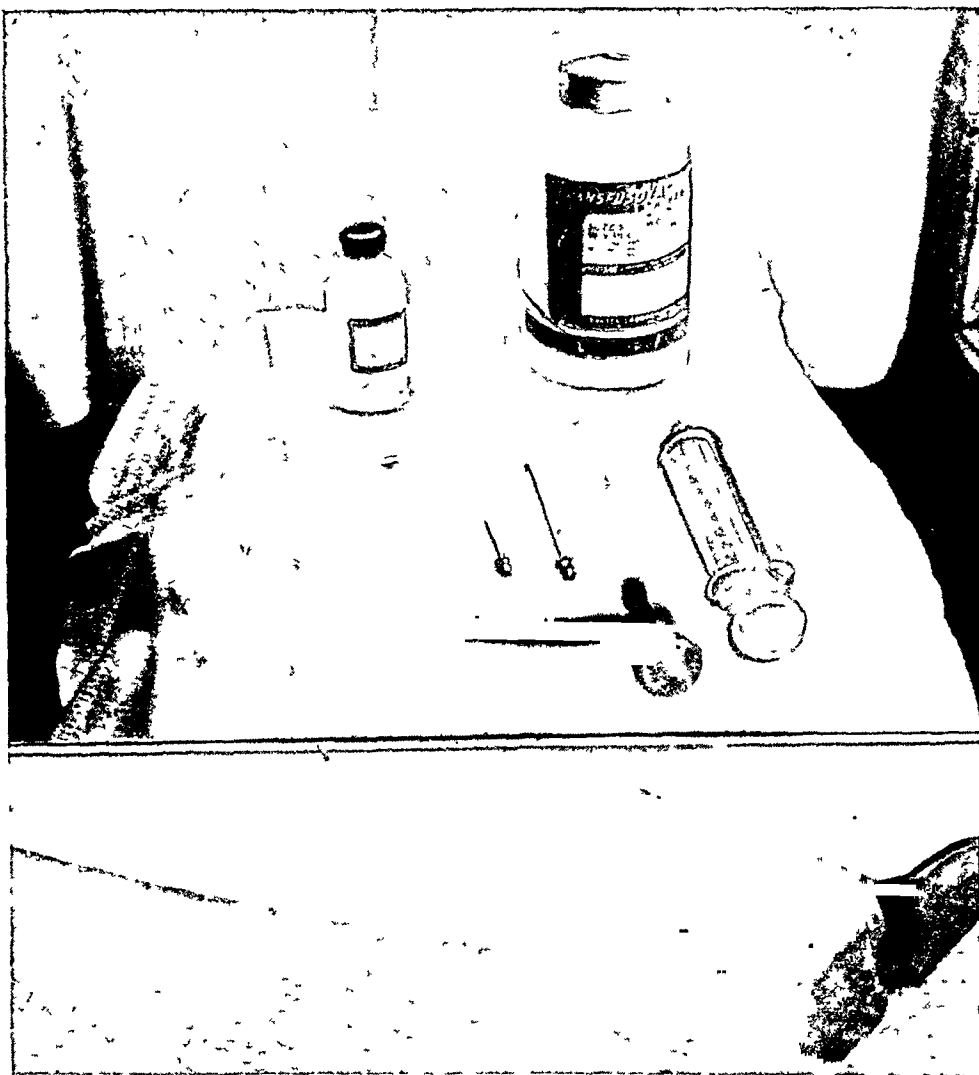


FIG. 1.—Apparatus used for aspiration of chest fluid. The needles, syringe and valve with tubing and adapter are prepared in small sterile packages, making bedside thoracentesis extremely simple and practical.

FIG. 2.—Leaky tube for empyema drainage. The irrigating catheter is incorporated into the lumen of the drainage tube. The rubber flanges are approximated with an hemostat and then released after the tube is placed into the empyema cavity. The tube is easily removed by a moderate pull.

to administer the oxygen. We have not found the use of respiratory stimulants indicated or necessary in these cases. Early physiotherapy to the chest wall and to the shoulder girdle are extremely important in restoring normal pulmonary function. This was carried out after all soft-tissue wounds were healed. Ambulatory activity and physiotherapy were tolerated early; and we believe that these, coupled with repeated aspiration of hemothorax and the use

of penicillin have been instrumental in maintaining a low percentage of complications.

### CONTROL OF PAIN

Every effort should be made to avoid the use of respiratory-depressing drugs to control pain in patients with chest injuries. Intercostal nerve block is the method of choice. This has the great drawback of short duration and at times must be repeated frequently. The effect may be prolonged by making



FIG. 3.—Large tube closed drainage. The rubber cuff sutured to the skin with heavy silk maintains the position of the drainage tube.

the injection as close to the nerve root as possible and by blocking the third through the twelfth nerves. Complete blocking of the injured side of the chest will very often relieve distressing dyspnea and cyanosis by overcoming the splinting caused by pain. The relief of cyanosis and dyspnea by intercostal nerve block has at times been dramatic. The spasm of upper abdominal muscles is often relieved by this procedure and this fact has been helpful in ruling out penetration of the abdomen in conjunction with a chest wound. Small doses of codeine sulfate combined with one of the barbiturates are helpful in providing rest and pain relief. Morphine is almost never necessary when intercostal nerve block is available.

### FATALITIES

There were three deaths in the 402 cases, a mortality rate of 0.9 per cent. It is possible that other deaths may have occurred subsequent to evacuation from the hospital, but at the time of evacuation there were no patients in whom such a possibility was other than remote.

### ABBREVIATED CASE REPORTS OF FATALITIES

**Case 1.**—A soldier suffered a perforating wound of the left chest, which was treated by débridement and aspiration at a Forward Hospital. He arrived at this hospital on the eighth postoperative day, was ambulatory from the following day until his sudden death on the fourteenth postoperative day. The cause of death at autopsy was pulmonary thrombo-embolism, the source of which was found to have been in the pelvic veins.

**Case 2.**—A soldier suffered a penetrating wound of the left humerus and left chest. For tactical reasons he was brought to this hospital by ambulance the day after injury, with continuous oxygen administration *en route*. After multiple transfusions, operation was performed on the second day. Thoracotomy, with removal of clot, a metallic foreign body and in-driven rib fragments, was done. His course was stormy, and he expired on the seventh postoperative day with progressive oliguria. There had been no obvious transfusion reactions. At autopsy, aside from local wound findings, the important lesions

were in the kidneys. The pathologist reported the presence of severe tubular degeneration, and "hemoglobinuric nephropathy." This is the picture seen in so-called "transfusion kidneys."

**Case 3.**—A civilian suffered a perforating gunshot wound of the left chest, diaphragm and kidney. The kidney was shattered and was removed through a transdiaphragmatic approach. Progressive oliguria and uremia ensued, and he died six days after operation. Clinically, there was no evidence of intrapleural or peritoneal infection. Autopsy was not permitted and the condition of the remaining kidney could not be determined.

#### DISPOSITION OF CASES

The following table indicates the disposition of the 402 cases. The only definite end-results are the three deaths. We have mentioned the fallacy of "returned to duty" as an end-result. There are two larger groups in which we can do no more than state that, in our opinion, the chest lesions were healed; but because of other injuries or the need for further convalescence, it was necessary to evacuate them to the Zone of Interior or to rear echelons in the Zone of Communications. So far as the chest lesion alone was concerned, it was our opinion that no further surgery would be needed and that complete recovery could be expected. This is obviously open to criticism. It is certainly possible that retained intrapulmonary foreign bodies which we considered innocuous, may prove to be otherwise, or may perhaps be removed with the thought of preventing further damage. A small group has been listed as unknown, and comprise patients who were in the hospital for a too brief period to permit speculation as to their future course. It should be said that the majority of these were either prisoners of war or members of other Allied Forces.

I. Cases which will probably require no further thoracic surgery.....	359	89.3%
a. Returned to duty.....	63	15.6%
b. Evacuated to ZI.....	121	30.0%
c. Evacuated to CZ.....	175	43.5%
II. Other dispositions.....	40	9.8%
a. Evacuated—will need further thoracic surgery.....	8	
b. Evacuated because of cardiac damage.....	3	
c. Evacuated unknown.....	29	
III. Deaths.....	3	0.9%

#### SUMMARY AND CONCLUSIONS

(1) A study of 402 cases of penetrating or perforating chest wounds treated in a General Hospital during campaigns in Italy and France is presented.

(2) A low incidence of empyema, clotted hemothorax, operative procedures necessary and a low mortality rate are shown.

(3) It is suggested that early, frequent aspiration, adequate blood replacement and early ambulation are extremely important in the reduction of the incidence of complications.

(4) It is further suggested that definitive treatment of penetrating chest

wounds may be carried out most satisfactorily in the Forward General Hospitals.

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## THORACIC GASTRIC CYST

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THERE is a great variety of cysts which occur in the mediastinum. One of the more unusual types is of entodermal origin—the gastric cyst. We have found only 16 cases in the literature (Table I) and the rarity of the condition seems to justify this case report.

**Case Report.**—M. C., a 22-months-old white female child, was admitted for the first time to the University of Virginia Hospital, May 3, 1945, with a history of pulmonary symptoms since shortly after birth.

The patient was born in another hospital, of normal parents, after a normal pregnancy and uncomplicated delivery. She was the first of three children, apparently normal twins being born about one year later. The patient's first two weeks of life while still in the hospital were uneventful, but soon after she was taken home she developed symptoms of a "cold," with a slight cough, nasal congestion and low grade fever. These symptoms persisted until the age of four months when she began to have severe paroxysms of coughing accompanied by cyanosis. Her voice became hoarse, and a diagnosis of "membranous croup" was made by the family physician. A chest film at that time is said to have revealed evidence of pneumonia. These symptoms, wet paroxysmal cough, fever, hoarseness and episodes of cyanosis continued despite several courses of sulfonamide therapy. Serial chest films revealed what was interpreted as a chronic pneumonia on the right side, which, in view of the prolonged illness, was finally decided by her local physician to be a lipoid pneumonia. At the age of seven months, the patient coughed up a large quantity of bright blood, estimated at one pint by the mother. Smaller hemorrhages occurred several times within the next three days. Clubbing of the fingers was noticed at this time by the mother. Since then, until admission to this hospital, seven severe pulmonary hemorrhages occurred, each requiring hospitalization and multiple blood transfusions. Only in recent weeks had the persistently wet cough resulted in the expectoration of grossly purulent sputum.

The child had not developed normally. She had been able to sit alone for several months but still could not stand alone, and had made no intelligible sounds. Her appetite was fairly good, but sleep was interrupted by frequent coughing attacks.

**Physical Examination:** Examination of the patient on admission revealed a fretful, poorly developed, undernourished, and obviously chronically ill child, weighing 18 pounds. The temperature, pulse and respiratory rate were normal. The skin was cold and moist, and the hair was very scanty. Marked clubbing of the fingers and toes was present. The chest had an enlarged anteroposterior diameter, suggesting emphysema. Auscultation revealed coarse moist râles bilaterally from apex to base, the right side harboring the most marked signs. There was no appreciable dullness to percussion. The abdomen was moderately distended and the liver edge was palpable two centimeters below the costal margin. Nose and throat examination was negative except for much mucus in the pharynx. There were no palpable lymph nodes of significance.

**Laboratory Studies:** Urinalysis revealed a one plus albumin and 18–20 white cells per high power field of the centrifuged specimen. The hemoglobin was 14 Gm./100 cc., or 91 per cent (Haden). The red cell count was 5.81 million, and the white cell count was 19,000. The differential count of the white cells showed 44 per cent polymorphonuclear cells, 49 per cent lymphocytes, 5 per cent transitional monocytes, 1 per cent basophils, and 1 per cent eosinophils. (Three blood transfusions had been given the week prior to admission.) Stool examination was negative. The Shick and tuberculin tests were both negative. Culture of the sputum revealed a multiplicity of organisms, including *Staphylo-*



TABLE I  
THORACIC GASTRIC CYSTS  
(Reported in the Literature)

Author	Sex and Age	Functional Activity	Treatment	Result
1. Staehelin & Burckhardt, 1909	Female, 9 mos.	Inactive	?	Autopsy finding
2. Mixter & Clifford, 1929	Male, 22 mos.	Active	Drainage and excision	Good
3. Mixter & Clifford, 1929	Male, 7 mos.	Inactive	None	Autopsy finding
4. Smith, 1930	Male, 14 mos.	Inactive	None	Autopsy finding
5. Fischer, 1930	Female, 6 mos.	Inactive	None	Autopsy finding
6. Entz & Orosz, 1930	Male, 11 mos.	Inactive	Drainage	Died, verified at autopsy
7. Poncher & Miles, 1933	Male, 29 mos.	Active	Operation	Died on op. table
8. Boss, 1937	Male, 3 yrs.	Active	Operation	Died on op. table
9. Seydl, 1938	Female, 3 mos.	Active	None	Autopsy finding
10. Nicholls, 1940	Female, 3 yrs.	Active	Drainage and excision	Good
11. Schwartz & Williams, 1942	Male, 23 yrs.	Inactive	Excision	Good
12. Schwartz & Williams, 1942.	Male, 4 mos.	Active	Excision	Died
13. Carlson, 1942	Male, 4 mos.	Active	Excision	Good
14. Wyllie & Pilcher, 1943	Female, 12 mos.	Active	Excision	Good
15. Olken, 1944	Male, newborn	?	None	Autopsy finding in stillborn
16. Laipply, 1945	Male, 27 hrs.	?	None	Autopsy finding
17. Valle & White, 1945	Female, 22 mos.	Active	Operation	Died on op. table

*coccus aureus* nonhemolyticus, *H. influenzae*, unidentified micrococci, *Streptococcus viridans*, and a yeast-like organism never fully identified but apparently nonpathogenic.

**Roentgenologic Examination:** Roentgenograms of the chest revealed a marked mottled infiltration particularly in the right lower lobe but with some involvement also in the middle and upper lobes. There was a dense elliptical shadow in the right hilar region which was thought to be an enlarged hilar lymph node. No evidence of cavitation was seen. The left lung was essentially clear. A review of the old films taken at intervals since the patient was four months old disclosed similar hilar adenopathy and infiltration in the right lung.

Bronchograms revealed generalized bronchiectasis of the right lung and a large cavity in the posteromesial portion of the right lower lobe. The oil flowed readily into this cavity through a large bronchial communication (Fig. 1). The left side was normal.

Laryngoscopy and bronchoscopy were performed on May 8, 1945. The true vocal cords were reddened and edematous, but the movements were normal. The mucosa of the trachea and right bronchial tree was also subacutely inflamed and copious mucopurulent secretions were aspirated. The left bronchial tree presented a mild inflammatory reaction with a small amount of secretion. There was no evidence of foreign body, tumor or stenosis.

The diagnosis of bronchiectasis with an infected bronchial cyst was made. Since the condition seemed to offer a threat to life, surgical extirpation of the diseased lung was advised in spite of the poor general condition of the patient.

**Operation.**—May 14, 1945: One of us (A. R. V.) explored the right chest through a long posterolateral incision, entering the pleural space through the periosteal bed of the resected seventh rib. The pleural space was partially obliterated by numerous adhesions but no difficulty was encountered in mobilizing the lung except in the posterior gutter where the lower lobe was very densely adherent. Just above the diaphragm in the lower lobe there was a dense mass, apparently inflammatory, about the size of a hen's egg. This mass was presumed to represent the cystic area seen roentgenographically. With much difficulty this portion of the lung was separated from the parietal pleura, but in so doing the cystic cavity was broken into and the peripheral portion of the cavity wall, densely attached to the diaphragm and posterior gutter, remained behind as the mobilization of the lung was completed. The lung itself was obviously infected, there being areas of dense inflammatory infiltration from apex to base. Pneumonectomy seemed justified and feasible. Hilar dissection was attempted but enlarged hilar lymph nodes

and friable inflamed tissues rendered impossible the individual isolation of the vessels and bronchus. Therefore, the Shenstone tourniquet was placed around the hilar structures, and a transfixion suture of heavy silk was used to ligate the hilum *en masse*. The lung was then amputated. After release of the tourniquet, the bronchus and vessels were individually treated, the former with fine silk sutures and the latter with silk ligatures. The stump was covered with mediastinal pleura. At this stage in the operation the heart suddenly stopped, as if from vagal stimulation, and all attempts to initiate



FIG. 1.—Bronchogram showing cyst communicating with the right lower lobe bronchus. Arrows outline the cyst which is partially filled with iodized oil.

pulsations by constant massage and medications for 20 minutes were of no avail. Spontaneous respiration ceased several minutes after cardiac arrest.

It had been our plan to remove the remainder of the cyst wall from the diaphragm and posterior chest wall after the lung had been removed. Postmortem dissection on the operating table of the remaining portion of the cyst proved that complete excision would have been an impossible surgical feat. Closer examination of the lining of the cyst suggested typical gastric mucosa with rugae, and the true diagnosis was first suspected at this time. Further dissection found the remnants of the cyst to extend down through the diaphragm, in intimate contact with the inferior vena cava, the bodies of the vertebrae and the esophagus. Adjacent inflammatory tissue necessitated sharp dissection throughout, and even with the utmost care in order to preserve the specimen the inferior vena cava was entered. The cyst ended blindly about five centimeters below the diaphragm, without anatomic continuity with either esophagus or stomach.

*Pathologic Examination:* The specimens consisted of an infant's right lung and an irregular piece of tissue, measuring 11 x 5 centimeters. The external appearance of the lung revealed extensive pleural adhesions and a small cavity communicating with

the posterior portion of the right lower lobe. When the lung was sectioned, dilated bronchi were found throughout. A probe passed into the cavity easily entered a branch of the right lower lobe bronchus. The separate piece of tissue grossly resembled stomach wall, having a mucosa with characteristic rugae and apparent muscular layers. The cavity in the lower lobe mentioned above had a similar mucosal pattern.

Microscopic sections revealed bronchiectasis, subacute bronchitis and areas of pneumonitis throughout the lung. Sections through the cyst wall showed the elements of a normal stomach, with typical mucosa and muscular layers (Figs. 2, 3 and 4). One section taken through the bronchial communication with the cyst shows the juxtaposition of the gastric mucosa with the elements of the bronchial wall (Figs. 2 and 4).



FIG. 2.—Photomicrograph showing typical gastric mucosa and bronchial cartilage.

COMMENT: There are two kinds of gastric cysts, those that are acid-secreting, or functionally active, and those of which the mucosa is without functional activity. Even though the acidity of the cystic secretions was not determined in our case, the early manifestation of symptoms—primarily hemorrhage, is so typical of the proven functionally active cases in the literature, that we feel justified in classifying this case as an acid-secreting or functionally active cyst.<sup>10</sup> From a review of the literature, it is found that there are two constant characteristics of a gastric cyst—it always occurs in the posterior mediastinum and on the right side. The functionally active cysts usually manifest themselves by symptoms at an early age, whereas the inactive

ones may be discovered accidentally in a routine chest roentgenogram later in life.<sup>10</sup>

There are several theories about the origin of endothoracic gastric cysts. They have been ascribed to a pinching-off of an evagination of the embryonic foregut, to an intrathoracic vestige of the omphalomesenteric duct, and to a proliferation of an entodermal germ cell of the esophagus capable of producing gastric epithelium.

The cyst wall has all the elements of the stomach wall. Smith,<sup>12</sup> and



FIG. 3.—High power photomicrograph showing chief cells of the gastric mucosa of the cyst.

Stachelin-Burckhardt<sup>13</sup> have each reported a case which exhibited both gastric mucosa and ciliated stratified respiratory epithelium in the same cyst. Boss<sup>1</sup> has described a case in which the intrinsic nerves and ganglia of the gastric musculature were identified. In our case, the cyst perforated the diaphragm and terminated in a blind sac about five centimeters below it. To our knowledge this feature has not been reported in the literature. It did not communicate with the stomach or the esophagus. Erosion of bone may be caused by the cyst, as reported in one of Mixter and Clifford's cases.<sup>6</sup>

The most commonly observed symptoms of gastric cyst are dyspnea, cyanosis, cough, dysphagia and sometimes, even in infants, hemoptysis. The most striking symptom of our case was the massive hemoptysis which necessitated admission to her local hospital on nine different occasions, with multiple blood transfusions during each period. Both Boss and Seydl reported

hemoptyses in their cases and attributed them to the presence of chronic peptic ulcers in the gastric cyst. In both cases the ulcers penetrated into the adjacent lung causing fatal pulmonary hemorrhage. Although no peptic ulcer could be demonstrated in the specimen from our case, it is probable that one had been present, since the cyst had eroded into the right lower lobe bronchus and was draining through the bronchial tree. Inasmuch as this

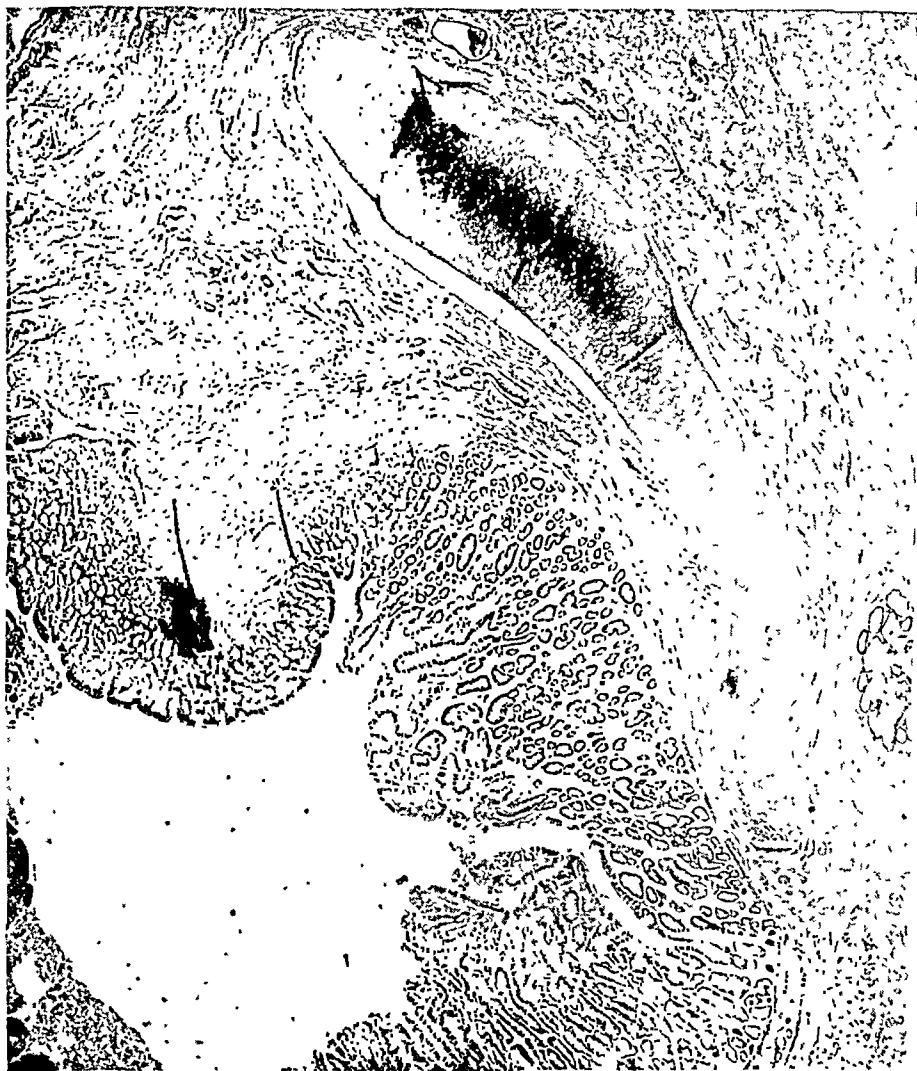


FIG. 4.—Low power photomicrograph of section taken at point where the cyst drained into the bronchial tree.

cyst was functionally active, the hemoptysis was probably due to bleeding from the ulcer itself and to the action of the gastric juice on the lung parenchyma and the bronchial tree.

The physical findings are variable but are usually those of pulmonary atelectasis or pneumonitis. There may be some cardiac displacement, scoliosis, or rarely, bulging of the chest. The findings in our case were primarily those of severe pneumonitis. The generalized bronchiectasis of the right lung, a complication resulting from the rupture of the cyst into the bronchial tree, has not previously been reported.

It is difficult to diagnose a gastric cyst during life with any degree of certainty without exploratory operation. However, the diagnosis is possible if gastric juice is aspirated directly from the cyst.<sup>2</sup> The cyst may contain from a few cubic centimeters of fluid to 400 cc. The fluid may be milky or clear, viscid or thin, or even sanguineous. The reaction is usually acid but may be neutral. Roentgenograms in both the postero-anterior and lateral projections are important, the lateral view particularly so, to show the cyst in the posterior mediastinum. Iodized oil bronchography is of use to show whether or not the cyst communicates with the bronchial tree and if so, to demonstrate its size, shape and location. In our case a diagnosis of posterior mediastinal cyst communicating with the bronchus complicated by generalized bronchiectasis of the right lung was made preoperatively. However, it was not until the typical gastric mucosa was seen when the cyst was opened at operation that the correct diagnosis was suspected.

The only treatment for gastric cysts is complete removal. If only a minute amount of the mucosa remains in the chest it will secrete and cause further complications such as empyema or a draining sinus, with or without excoriation of the skin. To date surgical treatment has not been too successful. Of the 17 cases summarized in Table I, ten had surgical treatment. Five of these survived, representing an operative mortality of 50 per cent. Two of these had a successful two-stage operation (drainage and later excision) and three had a one-stage removal. The high mortality is probably due to several factors. The patients are usually infants; they are usually in poor condition for a major operation; anesthesia is difficult to administer; and the dissection of the cyst from the mediastinum is technically impossible in some cases. The last factor is due probably to adjacent inflammatory reaction from the functional activity of the cyst. In some cases where complete removal of the cyst is impossible in a one-stage operation, preliminary drainage is useful as a palliative measure.

#### SUMMARY

A case of thoracic gastric cyst with certain unusual features has been reported. The cases reported in the literature have been summarized and a limited discussion has been presented.

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# RESULTS FOLLOWING BANDS AND LIGATURES ON THE HUMAN INTERNAL CAROTID ARTERY

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IN THE SURGICAL TREATMENT of intracranial aneurysms it is at times necessary for the safety of the cerebral circulation to partially occlude the internal carotid artery as a preliminary step before total closure of the artery. For this purpose a band of fascia lata is preferable, although a band of dura or the fascial covering of the temporal muscle is equally effective. A partial ligation is necessary when the Matas test (digital pressure on the internal carotid for ten minutes) induces signs or symptoms of cerebral anemia and, therefore, indicates an inadequate collateral circulation at the circle of Willis. Reduction in the lumen of this artery (by a band) to one-half, or more, forces the collateral channels at the circle of Willis to enlarge and carry an additional load to the brain. In a week or ten days the resulting increased blood flow through the circle of Willis is sufficient to permit total ligation of the internal carotid in the neck, or intracranially, or both. In a group of patients in whom a band has been placed for this purpose and total ligation has later been necessary, the segment of the artery, including the band, has, at that time, been excised for gross and microscopic study, principally to learn what happens to the affected portion of the artery and to the band. Since the band is always applied just above the bifurcation of the common carotid it has been necessary to include in the resected segment of the internal carotid a small part of both the common carotid and the external carotid arteries.

The specimens for study are (1) those following partial ligation of the artery (six cases) (Fig. 1); (2) following total ligation of the internal carotid (one case), and total ligation of the common carotid (one case) (Fig. 2); and (3) a single case following ligation of the intracranial carotid by a silver clip (Fig. 2).

(1) Specimens following *partial* occlusion of the internal carotid by fascial bands (six cases):

There are six of these. In all of them the lumen of the internal carotid has remained patent, though greatly reduced in size. The intervals of time between application of the bands and removal of the specimens at operation were, 16, 18, 25, 27, 58 and 58 days. In only one was there any indication of a thrombus within the lumen; in this case the thrombus was a tiny non-obstructing caruncle-like fibrous nodule. This patient had highly sclerosed arteries and a high grade of hypertension. Whether this condition of the arteries or the band was responsible for the thrombus is impossible to determine, though it would appear logical to assume that the band was at least a determining factor because the thrombus was directly under it. However, the intima was not infiltrated with cellular reaction.

In all cases there was an excessive bulbous mass of fibrous tissue about

the bands. The size of the swelling increases with time, and at the end of 58 days was perhaps four or five times larger than the original volume of the fascial band. In the specimens of 16 and 18 days the fibrous mass is about double the size of the original band.

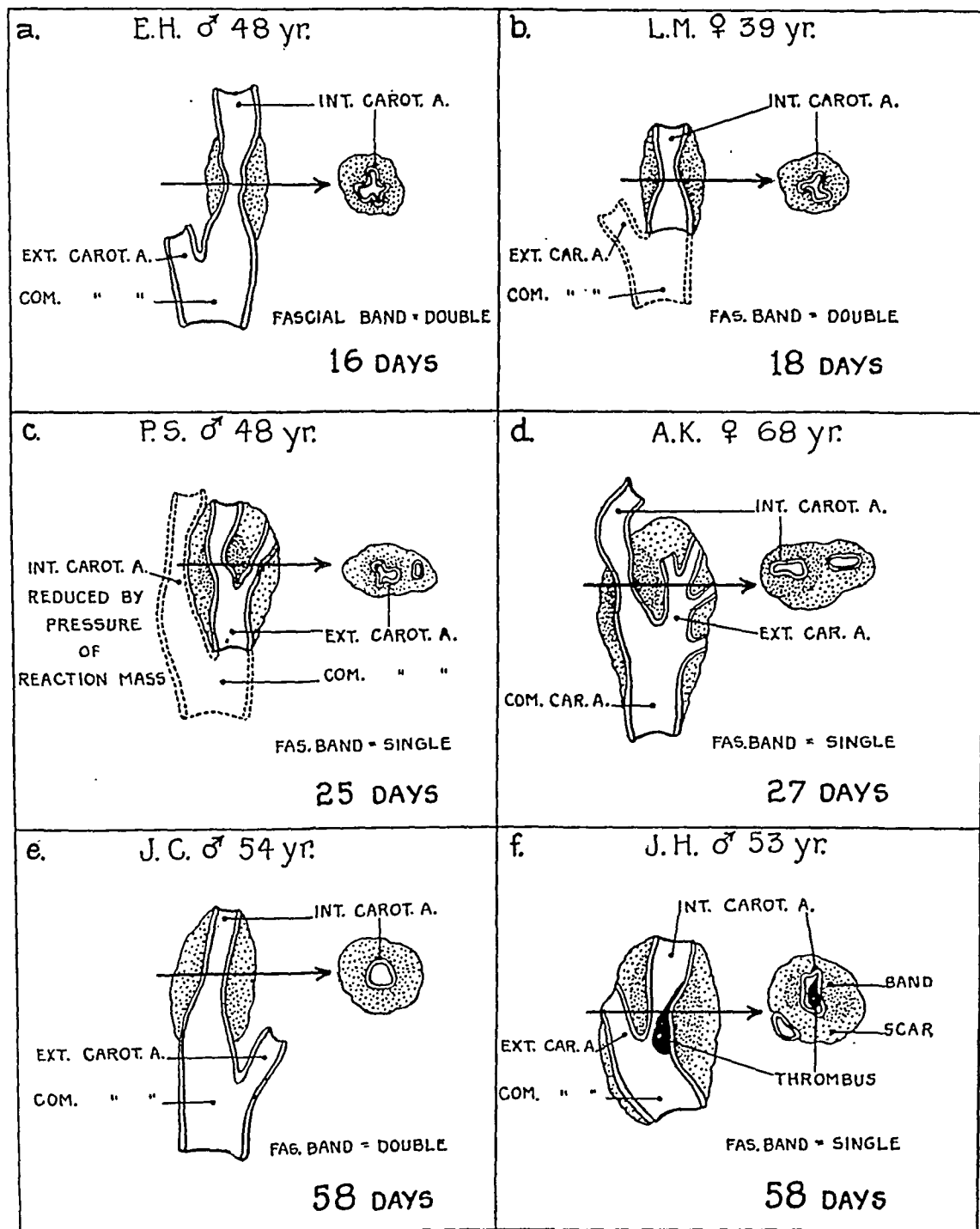


FIG. 1.—Showing partial ligation of the artery.

In all specimens the bands show marked fragmentation. Under the microscope the integrity of the bands is in large part lost in the gross and they are difficult or impossible to delineate in the older specimens. There appears to be a larger mass of fibrous tissue about the single than about the



double bands, and is probably due to the greater and more rapid disintegration of the single fascial layer from the arterial pulsation.

A rather surprising histologic finding is the absence of any reaction throughout the intima of the arteries, there being no tendency to vascular rupture (Fig. 3).

In five of the six specimens the cross-section of the vessel shows marked wrinkling of the inner lining (in the gross), but in one specimen (58 days) the lumen was almost perfectly circular (Fig. 1).

(2) Thrombus formation within the carotids following *total* ligations (two cases) (Fig. 2):

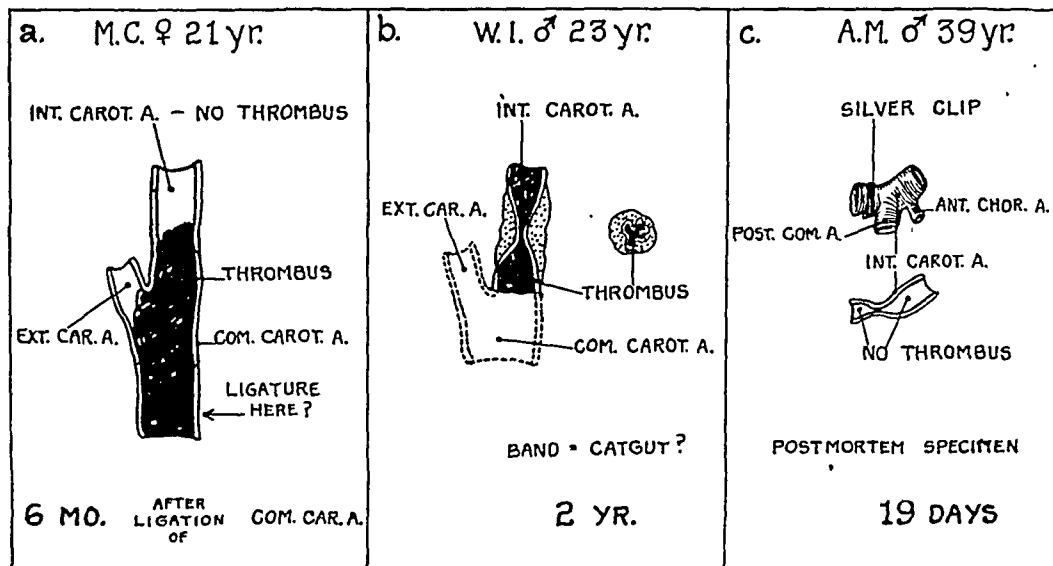


FIG. 2.—Two specimens in which (a) the common carotid artery; and (b) the internal carotid artery had been ligated, elsewhere, six months and two years, respectively, before removal of the segment of the carotid arteries; and (c) the results following the application of the silver clip to the intracranial portion of the internal carotid artery 19 days after its application. It shows absence of thrombus on either side of the clip. The extent of the intra-arterial thrombus following the total ligation is shown as far as could be determined from the examination at operation.

In one case the internal carotid had been ligated two years earlier (elsewhere), and in another the common carotid had been ligated six months before (elsewhere). In each, the vessel was thrombosed for a considerable distance. The extent was determined by palpation of the arteries and by opening the internal carotid. In the case of the previously-ligated *internal* carotid, the common and the external carotid arteries pulsated freely but the internal carotid was thrombosed higher than our exposure; the upper limit of the thrombus could, therefore, not be determined (Fig. 2b). In the case of total ligation of the *common* carotid six months earlier, the common carotid was totally occluded lower than our exposure and about two centimeters into the internal carotid: when the internal carotid was opened at this level there was bleeding from the cranial end but none from the cardiac end, which was full of firm thrombus; the external carotid was patent up to the bifurcation (Fig. 2a). In this case there was extensive new endothelial-

lined vascular spaces within the thrombus, but there is no evidence that they were continuous and the absence of bleeding proves that they were not.

It is clear from these two cases that the extent of an intra-arterial thrombus resulting from total ligation of an artery is variable and unpredictable and is *not*, as has been frequently stated, limited by "the first sizable branch" (the external carotid).

(3) The single specimen taken 19 days following application of a silver

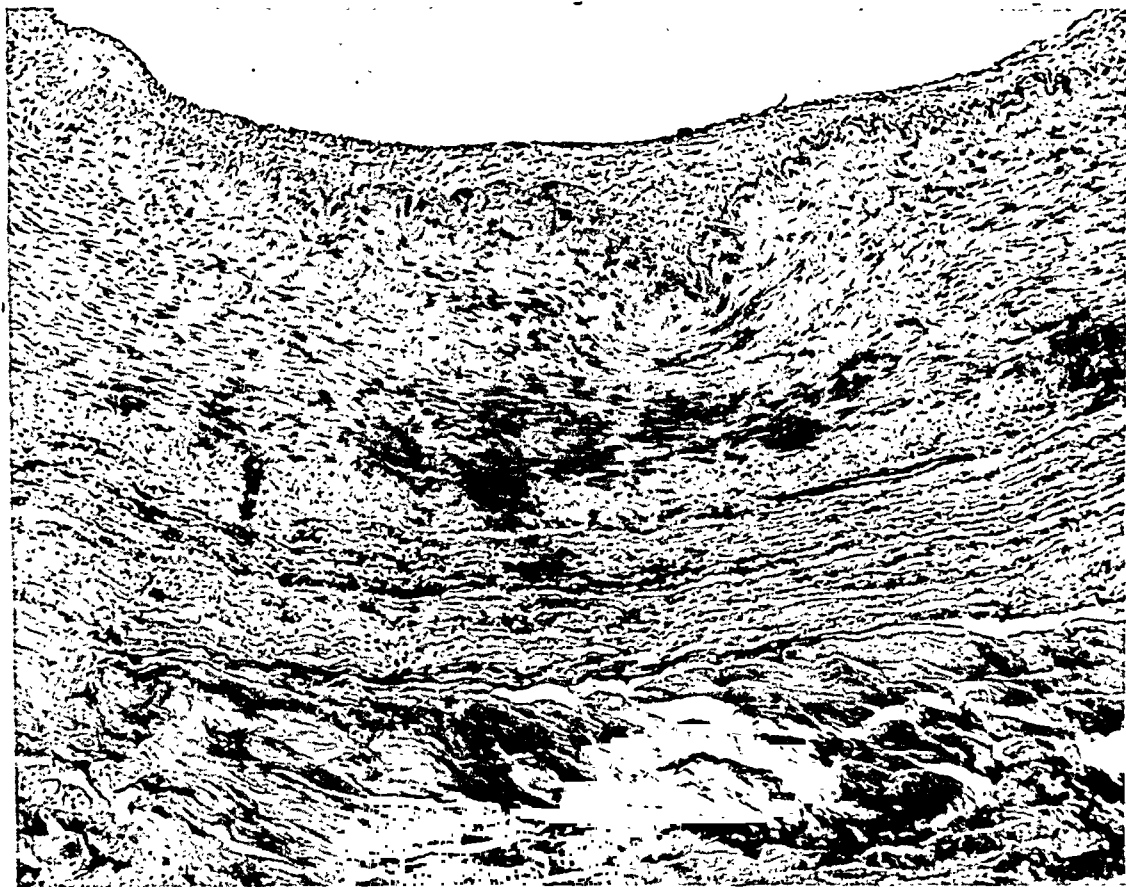


FIG. 3.—Photomicrograph 58 days after application of the fascial band. None of the coats show signs of necrosis. The elastic membrane is intact. The fascial band on the exterior is considerably fragmented. ( $\times 60$ )

clip to the internal carotid is included because there was no thrombus on either side of the clip (Fig. 2c). This we have observed on at least four other occasions when the site of the clip has been subsequently exposed at a second operation; we were surprised to find the vessel patent both above and below the clip. That a thrombus is consistently absent after the application cannot, of course, be stated without many more observations. However, in a series of 38 intracranial "clippings" of the internal carotid there has never been clinical evidence of cerebral thrombosis. The absence of thrombus formation within the artery in this experiment is exactly the same as the results obtained by Doctor Halsted in a large series of dogs when aluminum bands were used. The flat silver clip is doubtless comparable in its action to that of an aluminum band on the internal carotid in the neck. And when the greatly reduced size of the intracranial portion of the internal carotid is

considered, the size of the silver clip is relatively the same as the larger band in the neck.

#### TYPES OF BANDS

In 1905, Professor Halsted made extensive studies on the aorta and carotid with bands of different kinds. He gave up fascia lata because it disintegrated rapidly under the pulsation of the vessel. His final choice was an aluminum band for which a specially contrived roller placed the band around the vessel in a cylinder. It was then moulded with the finger until the desired degree of partial constriction or total occlusion was attained. From these studies several fundamental principles for vascular surgery were made, and have since remained unchallenged:

- (1) Whether the band is partially or totally occluding there is no thrombus formation within the arterial lumen.
- (2) Thrombus formation is due to injury to the intima by ligation (this was known before).
- (3) Beneath an aluminum band the vascular wall becomes completely necrotic.

In his earlier experiments (1905) Doctor Halsted stated that under partially constricting bands the wall of the vessel did not become grossly necrotic after ten days. In his last published paper (1924), however, he stated that "the included portion of the wall always dies whether the occlusion is *partial* or *complete*."

Reid (1916) carried on another series of experimental studies for Doctor Halsted, using bands of various metals, and concluded that the wall of the artery always atrophied beneath the band. This was the investigation that changed Doctor Halsted's opinion on this point. In the earlier experiments he had not made microscopic examinations of the arterial walls.

Matas (1911) used aluminum bands on the big vessels for occlusion of the carotids, because it could be safely removed if the cerebral circulation should be inadequate. An ordinary ligature would cut through all the coats and, therefore, could not be removed without danger of rupture. He also demonstrated that necrosis of the vessel was not visible until 96 hours after the band had been applied. He has since had occasion to remove the bands from the carotid in several instances, and with return of cerebral function. An interesting case of C. H. Mayo's was referred to by Doctor Matas in this early publication: A patient upon whose carotid a thin tin band had been applied developed cerebral symptoms (loss of vision); he loosened the band but did not remove it; the vision returned and the band healed in place. Doctor Matas emphasized the fact that a ligature could not have been removed.

Since this publication the invaluable Matas test for the efficiency of collateral circulation has been introduced, and when correctly applied, the surgeon no longer guesses but can know with certainty before operation whether or not a total occlusion will be tolerated. Doctor Matas, I think, still uses the metal band on the carotid because of the reputed disintegration of fascia.

Pearse (1932) titled a publication "The Impracticability of Using Fascia for Gradual Occlusion of the Large Arteries," and concluded that at that time Halsted's aluminum band was "the best device today." In a series of experiments upon the aorta of dogs the bands of fascia were found to disintegrate and relax even when six or eight thicknesses were used. In some instances the walls of the artery ruptured beneath the bands (25 per cent). He reasoned that fascial bands were unreliable and dangerous.

Despite the above experimental evidence bands of fascia lata have been used in all of our cases, and without an untoward result of any kind. They are sewn in place at the desired constriction of the artery after the method of Kerr (1925). They have served their purpose with complete satisfaction in a series of 30 cases to date.

The danger of rupture of the internal carotid from a viable tissue is, I think, less than from a metal band. Moreover, they are just as easy to remove if that should be necessary when the constriction has been carried too far. In three of our series the bands have been removed and later replaced with less reduction of the lumen. Complete cerebral function returned in two, and partially in a third.

In the microscopic sections the intima is always viable and unchanged from the normal, *i.e.*, it does not disintegrate as under an aluminum band. There is no doubt that the fascia does disintegrate (Fig. 4), even when doubled, but the doubling decidedly delays the fragmentation. However, this probably is not so important in the carotid because there is a greater mass of fibrous tissue about the single bands and is probably roughly proportionate to the disintegration. The volume of connective tissue produced about the band is doubtless an important factor in reinforcing the vessel. Certainly, in no instance has there been any tendency of the lumen to expand. On the contrary, I should guess that the mass of fibrous tissue probably gradually constricted the lumen farther than obtained at the time the band was applied.

Most of the experimental work has been done on the aorta—a very much more severe test for bands than the internal or common carotid. When a band is applied to the aorta there is no other sizable preformed channel by which the arterial load can be diverted to the lower part of the body. The anastomotic channels develop slowly through the dilatation of tiny communicating channels. After the carotid is tied, an increased volume of blood is immediately transferred to the other carotid and thence through the sizable trunks of the circle of Willis, which can quickly enlarge. I should not even suggest that fascial bands would be applicable to the aorta of human beings even when applied in multiple layers: but for the carotids the results are undeniable.

#### PROGRESSIVE OCCLUSION OF THE LARGE ARTERIES

A method by which a progressive constriction of a large artery could be induced has, until recently at least, been unsuccessful. Doctor Halsted's experimental efforts were originally begun with the hope that a partially occluding band could be still further constricted by a subsequent manipula-

tion of the band by reopening the wound, thus making the final occlusion by steps instead of gradually. All earlier attempts to induce progressive occlusion had been through ligatures or clamps that were left extruding from the wound, and these always became infected, with disastrous results. But Doctor Halsted's bands have not been satisfactory because the wall of the vessel became necrotic.

Pearse (1940) has recently introduced, in experimental studies, a very ingenious method of gradual compression of large vessels which may or may not prove to be the answer. A layer of cellophane is wrapped around the



FIG. 4.—Photomicrograph showing marked fragmentation of the fascial band. The remains of the band are in small islands. This was a single band. The specimen was taken 58 days after the band was placed. ( $\times 75$ )

aorta and tied: a violent and extensive cellular reaction (doubtless of chemical origin) engulfs the band and gradually constricts the vessel until it is completely closed. This fibrous mass has been strong enough to prevent rupture of the vessel. Its practicability in human cases has, I think, not been tested. Its use on the carotid artery may or may not be as good as fascia. It could hardly be better. At most, it could only make a subsequent total ligation unnecessary; and to do this would require a certainty in its efficacy which could only be acquired by an extended experience. Fortunately, in the carotid attack a progressive occlusion is not essential for success. Here, again, ligations of the carotid and of the aorta are entirely different problems: what applies to one does not apply to the other. It should also be noted

that the reaction to bands of fascia lata is precisely similar to those of cellophane except in degree. The mass of fibrous tissue is, at least, an effective support for the arterial wall and it may, and probably does, cause progressive occlusion of the lumen.

#### INTRACAROTID THROMBOSIS FOLLOWING BANDS AND LIGATURES

It is very probable, but not certain, that a thrombus always develops in time on either side of a *ligature* on a large arterial trunk. Our two cases are examples. This is doubtless due to injury of the intima, which must always occur. And yet bands of fascia and aluminum, whether partially or totally occluding, appear not to do this. Doctor Halsted's experiments with aluminum bands and ours with fascia are proof of this.\*

The development of a thrombus after ligation and its absence following application of a band, are the reasons for a better form of ligation of the internal carotid. When a clot forms in the carotid it may break off and send an embolus into the cerebral arteries, with disastrous results; or the clot may propagate from the site of the ligature and pass directly into the cerebral vessels with the same result. Either of these eventualities is the explanation for the hemiplegias and deaths that occur 12-96 hours after carotid ligations. I am certain that they can be avoided either by totally occluding bands of fascia or by ligating *over* a band of fascia. The ligature does not then cut the intima. The latter procedure is probably preferable and more certain. One should never trust to a ligature directly applied to a large artery.

That injury to the intima of a large artery was responsible for thrombus formation is not a new conception. The following interesting excerpts from that great English master of surgery, Sir Charles Bell (1816), show how long this has been known. "I was taught carefully to avoid drawing a ligature so tight around an artery as to cut the inner coats; and this remark was repeated both in the dissecting room and the hospital." He then made some facetious remarks about theoretic surgeons who were trying to revolutionize the surgery of blood vessels, by tying the artery and at once removing the ligature. He predicted that some bright young surgeon would put it in practice and "it was done that winter," for an aneurysm of the leg. "But as it did not cure the aneurysm, the medical world heard nothing about it." "To correct this erroneous, because partial, view of the subject, I made the following simple experiment. I put a cord around the carotid of a dog without drawing it. The ligature lay in contact with the coats of the artery but did not press upon them, nor interrupt the flow of blood through them. I was certain of the result: a clot formed where the artery was irritated by the presence of the ligature and the vessel was obstructed at that part."—"the effect of the ligature is perfect." "After this experiment I should be as fully authorized to commit the folly of using a ligature to the artery of an aneurysmal

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\* It cannot be said that a thrombus will *never* occur, but in none of our cases has it been seen. However, in one case of his and one of mine there was a tiny nonpropagating, nonobstructing caruncle-like body in the lumen under the band, and presumably related to the band.

limb, thus, simply putting it around the vessel without tying it (Fig. 5), as they who propose to effect the same purpose by cutting the coats of the vessel with the ligature and taking it off again"—and concludes that "a surgeon ought never to consider himself at liberty to deviate from a line of practice which experience has taught to be effective and safe."

One cannot be certain to whose new experimental studies Bell referred, but just at that time three important contributions were made in England on the use of ligatures on large arteries. They were by Jones (1802), Travers (1813), and Lawrence (1815), and doubtless these stimulated his sarcastic remarks. The particularly pertinent experimental studies of Travers had just appeared and very probably provoked his attack.

Jones showed that (1) a tightly drawn ligature always cut the two inner coats, only the adventitia holding fast. (Jones says this was known to Desault and was demonstrated to him [Jones] by Thomson, a surgeon in Edinburgh); and (2) a plastic exudate "lymph from the vasa vasorum" at the site of and induced by the ligature was responsible for the closure of the artery.

Travers found that after 12 hours a ligature performed no function because the reparative processes induced by injury to the vessels caused its permanent closure and, therefore, "it seemed probable" that the ligature could be removed after that time and the "dreaded inflammations" induced by the foreign body, *i.e.*, "liberation from the vessel by an ulcerative process" could be avoided. It will be recalled that at that time the long sutures were left emerging from the wound and were later (2-3 weeks) sloughed out.

Lawrence then introduced silk as the ligature of choice and began the unorthodox method of cutting the ligature close to the knot, leaving it to be disposed of by nature. Many of the wounds healed by first intention, but he was at a loss to understand what eventually happened to the ligature. Shortly thereafter the absorbable suture was introduced by Physic, of Philadelphia.

The relation of thrombus formation to ligatures has long been disputed. It was long ago proposed that it was responsible for the closure of the artery. Travers decried its importance saying it was variable, "it may be present in 12 hours and may not be formed in 24 hours." Senn (1885) found it to occur (as did Pouteau over a century before) only at times. He quoted Porta, one of the earliest great names in experimental vascular surgery, as finding thrombi in 87 per cent of the ligations, and Schumann in 33.3 per cent. Delpine and Dent (1891) found, in a series of sheep, a distal thrombus in only one and peripheral in all. Ballance and Edwards (1891) reported a thrombus in every instance, whether the intima was injured or not.

In retrospect, it is now clear that the thrombus above and below Bell's non-constricting band was due to infection which, of course, he could not know. The same explanation doubtless holds for the results of Delpine and Dent, and of Ballance and Edwards (1891), whose experiments were performed before Lister's discovery had taken effect.

Doctor Halsted's experiments, performed under strict surgical asepsis,

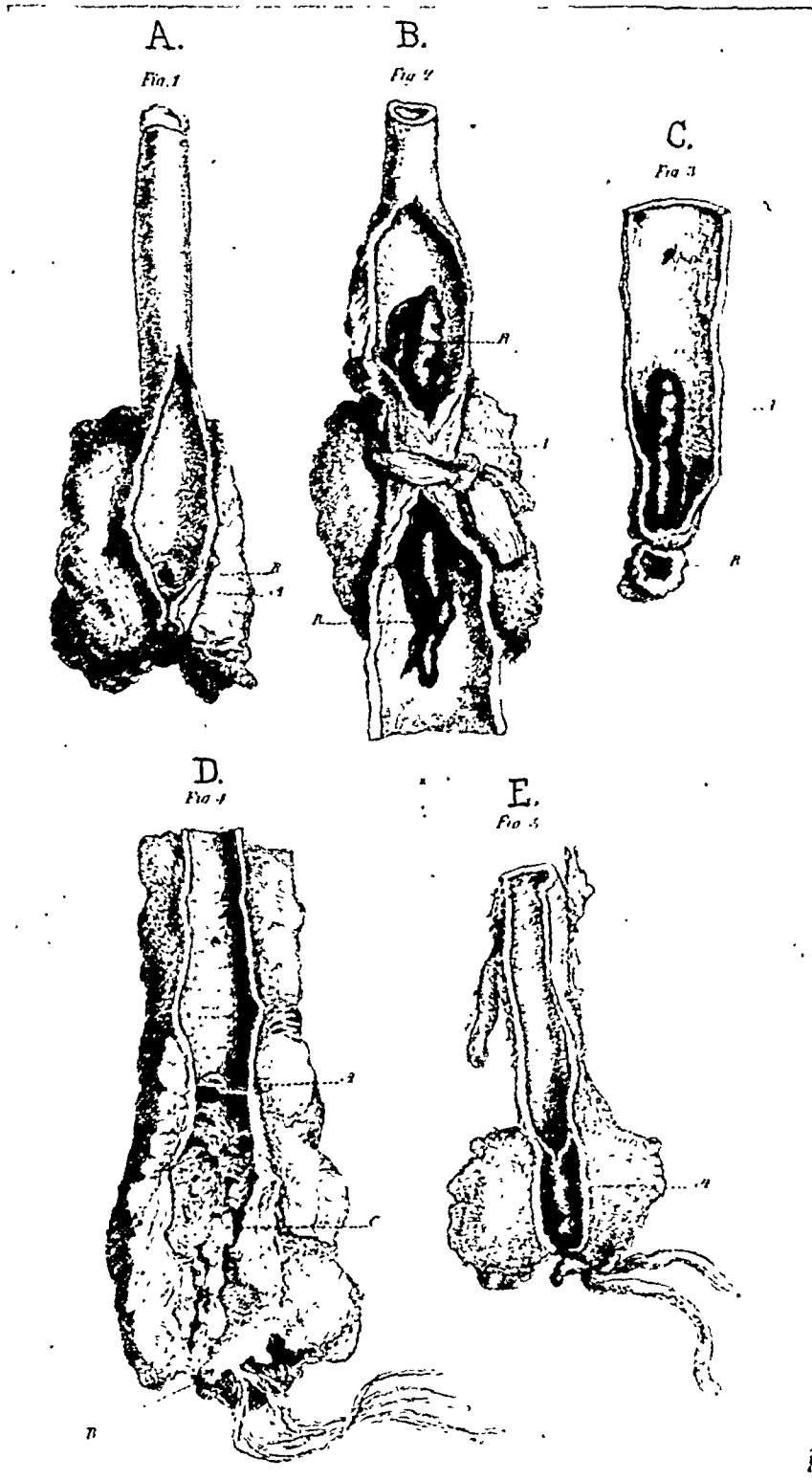


FIG. 5.—Plate retouched from Sir Charles Bell, 1816: These figures show principally the development of thrombi within the artery. Figure B is particularly interesting since a large ligature was placed around the vessel without constricting it, a clot forming, nevertheless. This was, of course, due to infection, a cause that was not known at that time. The proliferation of tissue around the ligatures is shown in Figures A, B and D. Figure D shows "the coats of the artery included in the common cellular tissue."



gave the answer when sepsis was excluded, and our human cases are exactly the same.

The conception that a thrombus ended at the nearest sizable branch, probably dated from Jones' experiments (1802). Soon thereafter, Travers (1813) emphatically stated that the thrombus "is not bounded by collateral branches but extends into them." Ballance and Edwards also concluded that "the length of the clot, either above or below the ligature, is not dependent upon arterial branches into and beyond which the clot may not pass." In Figure 5 (Bell's plate, Fig. 1) Bell's sketch shows a small thrombus at the site of the ligature and stopping at the mouth of an entering artery. Bell believed in this rather prevalent impression despite Travers experiments that denied it. In an earlier publication\* I included a drawing of a spontaneous propagating and noninfective thrombosis that covered the entire course of the internal carotid and passed through the anterior and middle cerebral arteries and the posterior communicating arteries. One of the cases (Fig. 2a), here reported, shows that the external carotid was no barrier to its progress, and in the other case (Fig. 2b) the thrombus stopped part way up the internal carotid where there was no branch.

#### SUMMARY

(1) Six specimens of the human internal carotid were removed at operation for microscopic study at varying periods of time (from 16 to 58 days) after partially occluding bands of fascia lata had been placed on the vessels. Two specimens of the same vessel were studied for the extent of propagation of intra-arterial thrombosis following total occlusion of the internal carotid in one case and of the common carotid in the other. A specimen of the intracranial internal carotid was removed at necropsy 19 days after a silver clip had totally occluded the artery.

(2) Bands of fascia lata, either single or double, were used in these and 24 additional cases, and were perfectly satisfactory in every way.

(3) Although the bands disintegrate, a dense mass of connective tissue surrounds the fascia and prevents the artery from reëxpanding. Whether this mass of connective tissue produces an additional *progressive* constriction of the artery is not certain.

(4) The arterial wall does not become necrotic under the fascial band; as it does under an aluminum band. The intima is unchanged and shows no cellular reaction.

(5) Except for one tiny caruncle-like localized and nonoccluding thrombus in an elderly person with very sclerotic vessels there was no thrombus formation.

(6) In one patient whose *internal* carotid had been completely ligated (elsewhere) two years earlier, the thrombus completely filled the internal carotid higher than our incision in the neck but the common and external

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\* Zentralblatt für Neurochirurgie, 1937.

carotid arteries were patent. In the other patient, whose *common* carotid had been ligated (elsewhere) six months earlier, the common carotid was thrombosed lower than our exposure; the external carotid was patent and the thrombus in the internal carotid extended about two centimeters above the bifurcation, after which the artery was patent (it was divided at this level). The latter case demonstrates that the termination of a propagating thrombus is not determined "by the nearest sizable branch."

(7) The single case of a "clip" totally occluding the intracranial portion of the internal carotid, demonstrates the absence of an intra-arterial thrombus 19 days after application of the clip. In at least four other cases that have had reexploration of the intracranially-clipped carotid (in carotid cavernous arterio-venous aneurysms) the absence of a thrombus on either side of the clip has been demonstrated by palpation of the vessel. This is, therefore, a disadvantage, when thrombus formation is desired to cure the aneurysm.

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# GASTRIC RETENTION AFTER POSTERIOR GASTRO-ENTEROSTOMY FOR DUODENAL ULCER: PREVENTION AND TREATMENT

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POSTERIOR GASTRO-ENTEROSTOMY for duodenal ulcer is a relatively safe procedure and in properly selected cases gives excellent results. It is not the operation of choice for patients who are less than 50 years of age, for most patients who give a history of severe hemorrhage, or for those who have actively inflamed lesions. But in that large group of elderly patients who have obstructing duodenal lesions, often associated with cardiac, pulmonary or cerebral complications, extensive gastric resection is too hazardous and posterior gastro-enterostomy is an ideal operation.

Two complications of this procedure have tended to cast it into some disrepute; namely, (1) gastrojejunal ulceration; and (2) postoperative retention of gastric contents.

Gastric retention after an operative change in the continuity of the upper gastro-intestinal tract is a perplexing and often serious problem. This interference with emptying of the gastric contents and the associated prolonged loss of fluids and electrolytes may lead to death. In less disastrous cases, there is still the expense of prolonged hospitalization and occasionally further operative procedures. The true incidence of postoperative obstruction is unknown but it is probably high. In fact, this complication has become such a bugaboo that sometimes ill-advised gastric resection rather than gastro-enterostomy is performed in an effort to avoid this embarrassing sequela. Ideally, the proper treatment of gastric retention would be its complete prevention.

The literature for the last 40 years on the subject of gastro-enterostomy is full of sanguine communications (and this paper perhaps will be so regarded), each of which purported to present some change in preoperative preparation, surgical technic, or postoperative care which prevented regurgitant vomiting. From a study of the literature and our own experiences, it would seem best for each surgeon to evaluate all suggestions and use that technic which in his hands produces the best results.

## MATERIAL

During a three-year period, 200 consecutive cases in which posterior gastro-enterostomy had been performed for duodenal ulcer were observed. The first 100 cases (Group 1) showed such a distressing incidence of gastric

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\* Since this paper was written, Doctors Gray and Sharpe have entered the Armed Services, and are now Captain, Medical Corps, United States Naval Reserve, and Captain, Medical Corps, Army of the United States, respectively.

retention, necessitating further operation in six cases, that certain changes in operative technic and postoperative care were instituted. These principles were applied to the next 100 cases (Group 2).

The age and sex distribution, character of the lesion and temperament of the patients in the two groups were similar. The ratio of men to women

TABLE I  
CLINICAL DATA IN TWO HUNDRED CASES

	Group 1 (100 Cases)	Group 2 (100 Cases)
Men.....	79	80
Women.....	21	20
Age, years:		
20-29.....	0	2
30-39.....	2	2
40-49.....	27	20
50-59.....	55	50
60-69.....	13	25
70-79.....	3	1
Youngest, years.....	30	29
Oldest, years.....	72	76
Average age, years.....	53.03	54.13
Pathologic lesion:		
Subacute duodenal ulcer.....	20	18
Chronic duodenal ulcer.....	22	9
Obstructing duodenal ulcer.....	58	73
History of bleeding.....	12	7
No retention.....	64*	81
Retention in men.....	32	17
Retention in women.....	3†	2
Retention for less than five days.....	11	6
Retention for more than five days.....	24	13
Further operation required.....	6	0
Longest hospitalization, days.....	78	23
Average days in hospital in excess of 14.....	13.8	3.9
Deaths.....	2‡	0

\* One patient died three days after operation.

† One patient had serious retention.

‡ Mortality rate 1 per cent of 200 cases.

in both groups was about four to one (Table I). The youngest patient in Group 1 was 30 years of age, and the youngest in Group 2, 29 years. The oldest patients in the two groups were 72 and 76 years of age, respectively. The average age in both groups was essentially the same. Sixty-eight and 75 per cent, respectively, of the patients in these groups were between 50 and 70 years of age. The distribution of patients in the age-groups less than 50 and more than 70 years of age was essentially the same.

One surgeon (H. K. G.) selected the cases, using the same principles; superintended all preoperative and postoperative care and performed all operations, using the same anesthetic agent.

The changes in operative technic and postoperative care were the only variables in the two groups.

#### CAUSATIVE FACTORS

In general, retention of gastric contents after gastro-enterostomy may be divided into (1) the type that develops immediately after the operative procedure and progresses undiminished; and (2) the typical and more usual retention that develops between the seventh and tenth postoperative day.

The first type usually is the result of a mechanical disturbance which produces a malfunctioning or obstructed stoma. This disturbance has been ascribed by various authors to many causes, such as (1) a spur at the anastomotic site, occasioned by the festooning descent of the proximal and distal jejunal limbs; (2) the position of the anastomotic opening and direction of flow of peristalsis in the applied jejunum, whether isoperistaltic or retroperistaltic in relation to that of the stomach; (3) the long jejunal loop in the antecolic anastomosis which occasions filling of the proximal limb; (4) kinking of the duodenojejunal angle; (5) kinking or twisting of the distal limb of the jejunum as it leaves the gastric wall in an isoperistaltic anastomosis; (6) retraction of the anastomosis above the transverse mesocolon with angulation of the retracted jejunum; (7) peculiar valves of gastric mucous membrane or closure of the stoma by newly formed adhesions; (8) acute dilatation of the stomach; and (9) pressure on the jejunal limbs of the anastomosis by the middle colic artery if the anastomosis is made to the right of that artery.<sup>7</sup> Whatever the source, if the retention is caused by mechanical factors which manifest themselves immediately another operation is frequently necessary.

The second type of retention is less easily explained. It develops at about the time any severe gastrojejunal inflammation or edema of nutritional origin might occur, that is, between the seventh and tenth postoperative day. It is possible many times to predict at operation, on the basis of the patient's race, disposition, and temperament, the probability of postoperative retention. In these cases, the constitutional characteristics of emotionally unstable, high-strung, nervous persons become prognostic signs. Among the early theories of the cause of delayed retention are the presence of bile and alkaline juices in the stomach, an indefinite spasm at the stomal site and interference with innervation of the stomach and some disruption of peristaltic waves. At present, however, the consensus is that the obstruction is due either to a purely inflammatory gastrojejunitis or to edema of the stomal site, or most likely, to a combination of the two.

Postoperative gastritis probably extends beyond the new stoma. In the presence of an inflammatory process, delayed emptying of the stomach through the new opening into the distal jejunal limb is easy to understand. The presence of a certain degree of jejunitis in the distal limb is borne out by the fact that nearly all so-called gastrojejunal ulceration is in reality jejunal in origin. Most gastrojejunal ulcers are situated either in the distal limb of the jejunum or opposite the stoma on the jejunal wall.

Associated edema of greater or lesser degree is always present but probably is short-lived. As has been stressed for years by Ravdin, and others, it may be only part of a generalized edematous state occasioned by preoperative malnutrition, vomiting, restriction of fluids or anemia.

Ravdin, and others, have insisted that many patients are prone to have low plasma proteins after gastric operations as a result of a deficient preoperative diet. They have shown that these already diminished plasma proteins are lowered still further by the administration of saline postoperatively, with an

attendant increase in stomal edema. Enforced protein starvation due to the type of operation also supposedly increases hypoproteinemia. To combat this hypoproteinemia, Ravdin suggested early oral-jejunal feeding of amino-acids by the Abbott-Rawson tube. Chauncey, and one of us (H. K. G.), found, however, that the concentration of plasma protein is not the only cause of retention and is not the answer to the problem.

It has been suggested that, due also to faulty preoperative nutrition, certain vitamins are lacking in the blood stream and that this lack hinders healing of the stoma and promotes edema. Lanman and Ingalls showed that vitamin C is necessary for wound healing, and Thompson, Ravdin, Rhoads and Frank demonstrated that hypoproteinemia retards the healing of wounds. Vitamin B deficiency may lead to marked gastric atony and, indeed, such deficiency has been found in patients who have an atonic stomach without pyloric obstruction. Apparently the vitamin B complex as a whole is the necessary factor, for Heublein, Thompson and Scully were unable to demonstrate complete return of gastric tone by feeding vitamin B alone to patients deficient in the B-complex.

Obviously, there is no single cause for the distressing complication of gastric retention. A combination of all these factors is probably responsible, that is: (1) the personality, race, and temperament of the patient, his individual worries, *etc.*, (2) improper preoperative preparation, (3) the operative technic and (4) gastrojejunitis and edema of the stoma. The surgeon can do little to combat the first of these factors.

#### PREOPERATIVE PREPARATION

The preoperative preparation of patients who have duodenal ulcer has changed little since this study was begun and the patients in the two groups were prepared similarly. Transfusions of whole blood were given as necessary. In cases of pyloric obstruction, the stomach was emptied at least twice daily, and oftener if indicated. Fluids were given intravenously as necessary to replace this loss. These usually consisted of a solution of 5 per cent glucose in distilled water or 5 per cent glucose in a 1 per cent solution of saline. Vitamins in the form of thiamine chloride, brewers' yeast, ascorbic acid and haliver or cod liver oil were added.

#### OPERATIVE TECHNIC

Since Wölfler, at the suggestion of Nicoladoni, in Billroth's Clinic, first performed an anterior gastrojejunostomy and von Hacker a posterior anastomosis, both for carcinoma of the stomach, many different technics have been described.

The posterior anastomosis was used in the 200 cases in this series. The proximal limb of the jejunum was attached to the posterior wall of the stomach near the angle and the lesser curvature, and the line of anastomosis was extended downward and to the left, the distal limb leaving the wall of the stomach near the greater curvature, as suggested by W. J. Mayo, and others. The reasons for this position of the stoma seem sound.

Mayo's discussion of the anatomy of the region, 35 years ago, is appro-

priate still: "For convenience we will take the origin of the jejunum as being at the point in which the duodenum passes through the transverse mesocolon. The distal end of the duodenum lies behind the stomach when the latter is moderately distended and about one and one-half inches to the left of the middle line and one and one-half to two inches above the umbilicus. Its horseshoe-shape has its concavity directed to the left and upward and its exit is within about two inches as high as the pylorus. The transverse portion of the duodenum passes forward over the prominent vertebral column and backward to the left side of the spine to the opening in the transverse mesocolon. The terminal inch which marks the duodenojejunal juncture is directed upward and to the left, the mesentery of the proximal jejunum lying behind and the free surface of the intestine directed forward. The jejunum from its origin drops at once into the left abdominal fossa."

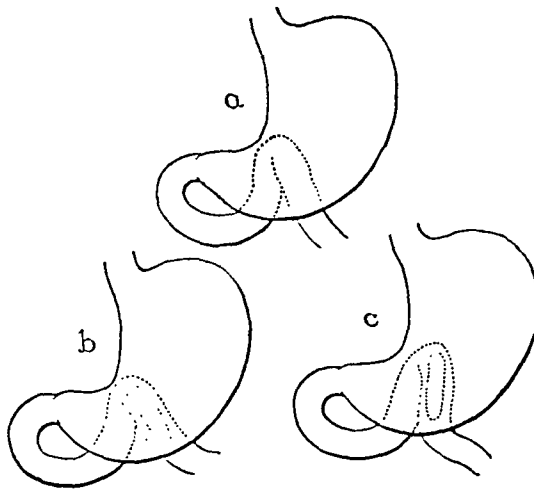


FIG. 1.—Relationship of first portion of jejunum to posterior wall of stomach: (a) normal; (b) gastro-enteric stoma made in location suggested by W. J. Mayo (1906), so as to avoid any distortion of the loop of jejunum proximal and distal to the anastomosis; (c) vertical gastro-jejunal stoma (slightly isoperistaltic) showing tendency to distortion of loop of jejunum proximal and distal to stoma.

This is important for two reasons. In the first place, if the jejunum is merely picked up and allowed to lie across the posterior wall of the stomach in its normal course it crosses the stomach from the patient's right and from above diagonally downward and to the left (Fig. 1a). If the anastomosis is made in this line, there is no angulation or distortion of the distal limb (Fig. 1b). If the anastomosis is more nearly vertical or isoperistaltic, running from above and downward to the right, angulation and distortion of the distal limb seem inevitable (Fig. 1c). In the second place, the fact that the jejunum drops at once into the abdominal fossa and even backward into the left kidney region emphasizes the necessity of carefully replacing the distal limb of the anastomosis behind and to the left of all other loops of intestine at the completion of the operation.

In speaking of the jejunum, Mayo continued: "Not only does it pass to the left but it gravitates backward into the left kidney pouch underneath the



splenic flexure of the colon, so that at a point four inches from its origin it lies on a plane to the left and posterior. This can be shown in a very practical way by drawing the transverse colon out through the abdominal incision, pulling it upward and to the right until the mesocolon is taut. This brings the beginning of the jejunum into view. It will readily be seen, therefore, that if the attachment is made to the stomach so that the proximal portion of the gastrojejunostomy is to the left and above, and the distal portion is directed to the right and below, we have introduced two serious displacements." This point is illustrated by Figure 1c. "The jejunum," Mayo said, "no longer falls in the normal manner to the left and backward, but is artificially caused to pass not only to the right but forward as it must ride the vertebral column or the structures immediately contiguous." The great portion of the stomach which lies to the left of the pyloric antrum acts in a storage capacity. Its muscular action is much less forceful than that portion of the stomach bounded by the horizontal line of the lesser curvature above. Therefore, the right edge of the new stoma should begin near the angle of the lesser curvature and proceed downward and to the left (Fig. 1b). This placement of the stoma was used in all 200 cases discussed in this paper.

The difference in surgical treatment of these two groups of cases was entirely in the line of suture. The position of the stoma and the method of securing the completed anastomosis below the transverse mesocolon was the same in both groups; however, in the first 100 cases (Group 1) only two rows of catgut were used in the anastomosis. After placing the clamps and guide sutures a continuous catgut suture of No. 0 chromic catgut was placed in the serosa of both the stomach and jejunum. The stomach and jejunum were opened and a second posterior row of continuous catgut suture was placed, taking all layers of the intestine. Even with the utmost care small, denuded portions unprotected by mucosa were left in the suture line. It was thought that such small surfaces perhaps were conducive to the development of gastrojejunitis, with its attendant edema. In the second 100 cases (Group 2), three rows of continuous catgut suture were placed, the first in the serosa, the second in the muscularis and submucosa and the third in the mucosa alone, taking care to protect the entire line of suture with mucosa, as suggested by Eusterman and Balfour (Fig. 2).

The incision employed was usually a high right rectus type, splitting the rectus muscle. The stomach, pylorus and duodenum were examined and in all 200 cases it was decided to undertake a posterior gastro-enterostomy for duodenal ulceration. For purposes of orientation, Allis clamps were applied to the anterior gastric wall, one just at the angle of the lesser curvature and the other diagonally to the left at the greater curvature. The transverse colon was pulled upward and to the right, drawing the transverse mesocolon taut by retraction in all directions. The proximal loop of jejunum usually came into view, but if not it could easily be grasped at the ligament of Treitz. Even if it should come into view easily, it should be checked not only to make sure of its identity but to provide as short a proximal loop as possible. The posterior wall of the stomach presses on the taut transverse mesocolon

and the approximate direction of the stoma can be seen by pressure on the Allis clamps already placed. An avascular region to the left of the middle colic artery was chosen and the mesocolon was opened in a line slanting upward and outward and to the left with the colon being held upward as described. The posterior wall of the stomach with its applied Allis clamps

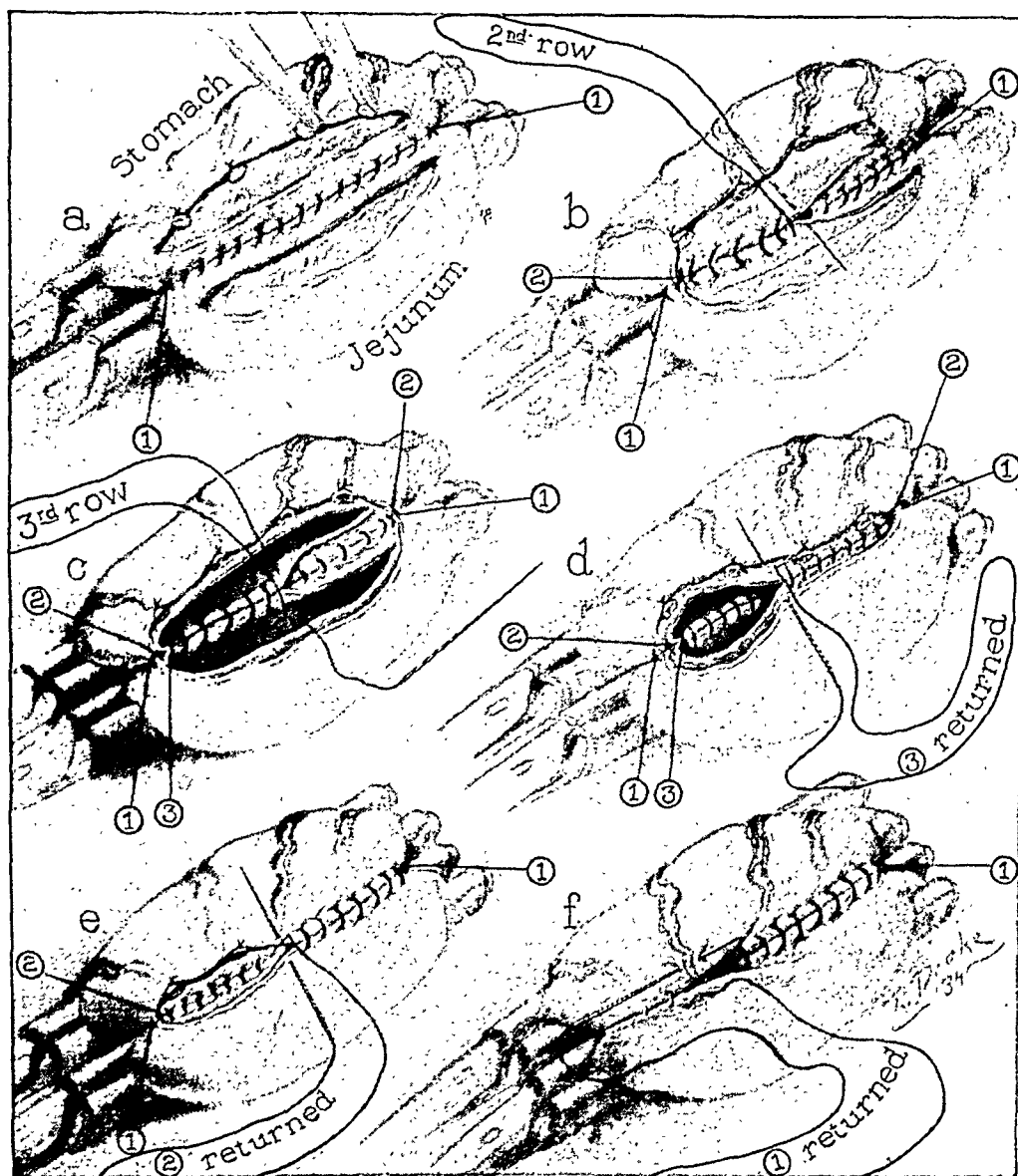


FIG. 2.—Steps in completion of the anastomosis of stomach and jejunum. The numerals indicate the order in which the rows of suture are made. ("The Stomach and Duodenum," by G. B. Eusterman and D. C. Balfour, W. B. Saunders Company, 1935.)

bulges through this rent and each clamp is removed from the anterior wall of the stomach and replaced in a similar position on the posterior wall. A straight rubber-covered clamp (Scudder) was placed on the stomach to include these clamps and to allow an anastomotic opening about 5 cm. in length. A similar rubber-covered clamp was placed on the jejunum, allowing 4 to 6 cm. for the proximal loop and making certain that the proximal loop of the jejunum was placed at the lesser curvature of the stomach. A

guide suture was placed at one end of the proposed anastomosis and the first row of continuous catgut suture was placed in the posterior row, using only the serosal layers of the jejunum and stomach, and leaving the suture long for use in returning across a similar layer in the anterior row. The gastric and jejunal walls were incised through the muscularis and submucosal layers to the mucosa itself and a second posterior row of continuous catgut suture was placed in these layers, again leaving the end long for future use. The mucosa was incised the full length of the anastomosis and a third line of suture approximated the mucosal layers of the posterior row, taking care to leave no raw, uncovered regions. This suture was returned in the first, or inner, anterior line. The rubber-covered clamps were loosened at this point to check any bleeding and the second anterior row of sutures was placed, using a continuation of the second posterior row. The placing of the third row of anterior serosal sutures finished the anastomosis (Fig. 2). At each angle one or two silk sutures were placed as reinforcement. The anastomosis was pulled well through the rent in the mesocolon, the cut edges of which were fastened with interrupted silk sutures to the wall of the stomach at least 2 cm. away from the anastomosis. The anastomosis should not be allowed to retract through the mesocolic opening and thus cause obstruction of the jejunal limbs. Finally, the entire anastomosis was carefully replaced in the abdominal cavity, making certain that the distal limb of the jejunum was well behind all other loops of intestine (Fig. 3).

This procedure was used in the second 100 cases. With the exception of the careful approximation of the mucosal edges with a third suture line, it was used in the first 100 cases likewise. No further operative procedure was undertaken in any case at the time of the gastro-enterostomy.

#### POSTOPERATIVE CARE

There was nothing unusual about the postoperative care in the first 100 cases. Adequate fluid intake was assured by either the subcutaneous or intravenous route, a 5 per cent solution of glucose in distilled water being the fluid of choice. A daily output of from 800 to 1,200 cc. of urine was maintained. Sips of water by mouth were allowed on the afternoon of the second day, or the morning of the third day and gradually increased. By evening of the fourth day the usual gastro-enterostomy feedings were tolerated and the intake of food gradually was increased. Aspiration of the stomach with the Levine tube was performed morning and night daily until the retained secretion was less than 150 cc. The inlying nasal suction tube was used only if retention developed. The patient usually was up on the eighth postoperative day and left the hospital on the 14th day.

The incidence of retention in the first 100 cases was distressing. In the second 100 cases, in addition to the difference in surgical technic, certain changes in postoperative care were instituted. The same principles of fluid balance and dietary management were observed. Aspiration was performed morning and night, as in the first 100 cases. The morning of the second day

the patient was given tablets of aluminum hydroxide gel (creamalin tablets) to chew slowly every three to four hours. As soon as water by mouth could be tolerated, neostigmine (prostigmine methylsulfate) was given to stimulate peristalsis and emptying of the stomach; 15 mg. of this drug was dissolved in 8 ounces (240 cc.) of water, and 2 ounces (60 cc.) of this solution were given four times daily. In those cases in which postoperative difficulty was anticipated because of the patient's temperament and racial characteristics, phenobarbital (luminal), 0.5 grain (0.032 Gm.), was given three times daily, and at the same time, atropine,  $\frac{1}{150}$  grain (0.00043 Gm.), or diphenyl acetic acid and diethylaminoethanol (trasantin), 75 mg. Since the retention usually developed on the seventh or eighth postoperative day, the amount of fluid taken by mouth was limited to 500 cc. from the seventh to the tenth postoperative day. A so-called dry gastro-enterostomy diet was allowed. The fluid by mouth never was taken with the feedings but rather between them. Subcutaneous infusion supplied the remainder of the necessary fluid intake on these days. In about the first 50 of these cases the stomach was aspirated morning and night of the seventh through the tenth postoperative day.

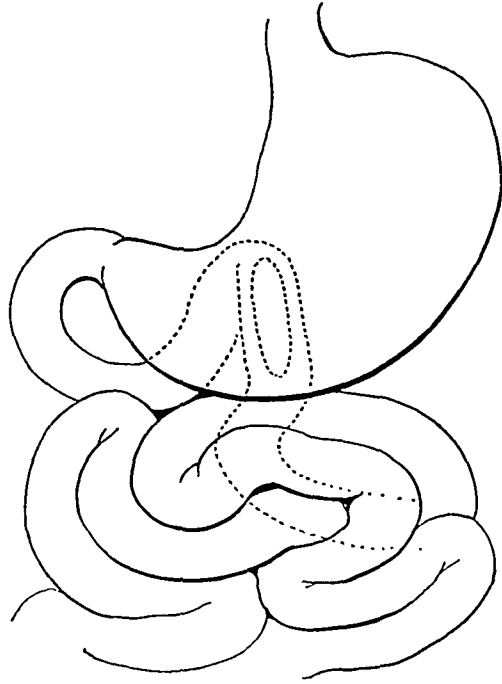


FIG. 3.—Relationship of the loop of jejunum distal to the stoma, and the remaining portions of the small bowel.

#### TREATMENT

No matter how carefully the prevention of gastric retention is planned, it occurs in a certain percentage of cases. However, the severity may be lessened by treatment. When gastric retention develops, the following treatment should be instituted: (1) Nothing should be given by mouth so that the stomach can have complete rest. (2) The fluid balance must be kept positive; that is, more fluids must be given parenterally than are excreted by the measurable urine and emesis output. The electrolytes lost by vomiting must be replenished. The ideal method, lacking a jejunal stoma and tube, is by subcutaneous infusion. Chlorides can be given thus, but glucose in solution must be administered slowly by the intravenous route. The amount and type of fluid given then depends on the output of urine and emesis and the levels of blood urea, carbon dioxide combining power of the serum, and blood chlorides as determined every second or third day. This equilibrium is easily disturbed and an alarming alkalosis or uremia quickly can develop. Frequent small transfusions of whole blood are beneficial. (3) Every effort

should be made to obtain normal bowel movements daily. Enemas may be given at first. One or two ounces (30 or 60 cc.) of castor oil may be left in the stomach by way of the aspiration tube after the tenth postoperative day. (4) The stomach must be emptied night and morning or oftener if necessary. No more than 300 to 400 cc. should be allowed to accumulate. If it becomes necessary to leave an inlying Wangenstein nasal catheter in place, constant suction should be avoided. If suction is used only 15 minutes of every hour, ample opportunity is provided for normal evacuation of some of the gastric contents, yet there is no danger of overloading the stomach. (5) Vitamins should be added to the intravenous solutions, particularly vitamins B and C. (6) Neostigmine (prostigmine methylsulfate), 1:2,000, may be given hypodermically, about 2 cc. four times daily.

If the principles already outlined concerning fluid balance are followed and the levels of the important chemical constituents of the blood are carefully checked, usually no operative procedure is necessary. If proper supportive treatment is given, the retention will clear up in most cases. However, in certain cases the blood chemistry values will vary from the normal range in spite of all efforts, and these patients will require further operation. The type of operation depends entirely on the condition of the patient and the ease with which the stoma, with its proximal and distal limbs, can be recognized. Many procedures have been recommended. Allen and Welch recently have emphasized the value of jejunostomy for the relief of a malfunctioning stoma. Jejunostomy alone is very effective, allowing the stomach to be put completely at rest. It is a relatively quick and easy procedure, necessitating anesthesia of only short duration. The operation usually gives good results even though probably no explanation for the retention is found. As a rule, the stomach is small, the stoma is of good size, and there is no evidence of obstruction. A gastrostomy may be performed on the stomach simultaneously. In this way all regurgitated gastric contents can be transferred to the tube in the jejunal stoma and the lost electrolytes can be replaced. A jejunostomy formula soon can be started and proteins may be easily given. In this way the surgeon has complete control of the situation and patients may do well for weeks with no oral feedings. It is important, finally, to stop the jejunostomy feedings and to allow the stomach to endeavor to empty itself. Continued jejunostomy feeding often will overload the jejunum and thwart normal gastric emptying.

Occasionally, an entero-anastomosis between the two jejunal limbs may be desirable. Often the patient is too ill or the performance of such a procedure simultaneously with the jejunostomy is technically impossible. If jejunostomy alone fails, an entero-anastomosis at a later date may be necessary.

Other procedures which have been recommended for correction of a malfunctioning stoma, but which have not been used extensively at the Mayo Clinic, are (1) second gastro-enterostomy, (2) duodenojejunostomy, (3) the insertion of the Abbott-Rawson tube at the primary operation and (4) the jejunoplasty procedure described by Hoag and Saunders.

### RESULTS

The type of lesion encountered at operation may be an important factor in the development of both retention and subsequent gastrojejunal ulceration. About a fifth of the 200 patients were thought to have subacutely inflamed duodenal lesions (Table I). The remainder of the lesions were chronic or had caused accompanying pyloric obstruction.

Of the 100 patients in Group 1, 64 had no regurgitant vomiting. Twelve patients gave a history of gastro-intestinal hemorrhage. Active bleeding at operation was present in only one case, and that patient died three days post-operatively of hemorrhage. In the 35 cases of gastric retention in Group 1, the condition cleared after the usual treatment in less than five days in 11 cases. Retention occurred in only three women, and in two of these it cleared in less than five days. However, in 24 cases the regurgitant vomiting lasted five days or more, and in six cases some type of secondary operation finally was necessary. Gastric retention in all 35 cases developed from the sixth to the tenth day.

In six of the 35 cases, reoperation was required. One of these six patients (16.6 per cent) died. This percentage indicates that the risk is too great unless operation is absolutely necessary. In three of these six cases, jejunostomy was performed; all finally were cured of regurgitant vomiting. In one case an entero-anastomosis between the two jejunal limbs was performed. This patient recovered satisfactorily.

In the remaining two patients, entero-anastomosis and jejunostomy were performed simultaneously. One patient, previously mentioned, died of inanition and hemorrhage three days later, making a mortality rate of 1 per cent for the 200 cases.

Of the second 100 patients, 81 had no difficulty as far as regurgitant vomiting was concerned. Nineteen patients had gastric retention of some degree. Of the 19 patients, only two were women; in both cases the symptoms were mild. In 13 of the 19 cases the retention lasted for five days or longer, and in six cases it lasted only a day or so. There was no need for further operation in any of these 13 cases. Seven patients gave a history of gastro-intestinal hemorrhage.

The expense of hospitalization is a serious problem with most patients. Obviously, persistent gastric retention can be treated only in a hospital and adds greatly to that expense. The usual length of stay in the hospital for gastro-enterostomy is about 14 days. In Group 1 the 35 patients who had retention were forced to remain in the hospital an average of almost twice that length of time. Some of these patients were in the hospital more than 30 days. In four cases the patients were hospitalized for more than 50 days in all. One patient left the hospital only after 78 days. In Group 2 no patient remained in the hospital more than 23 days. In the 19 cases in which the patients had retention, an average of only four days more of hospitalization than the usual 14 was encountered.

## SUMMARY AND CONCLUSIONS

A comparative study was made of two groups of consecutive cases of 100 each in which posterior gastro-enterostomy for duodenal ulcer was performed. The factors of age, sex, activity of lesion, position of stoma and technical skill were fairly constant. Because of the high incidence of postoperative retention in Group 1, changes in the technic of operation and of postoperative care were made in caring for the patients in Group 2 in order to combat postoperative gastrojejunitis, to promote peristalsis and to avoid overloading the stomach. These changes consisted of the use of three rows of sutures instead of two, as well as the postoperative regulation of fluid intake and the administration of medications, such as tablets of aluminum hydroxide gel (creamalin tablets), neostigmine (prostigmine methylsulfate), phenobarbital (luminal), atropine, diphenyl acetic acid and diethylaminoethanol (trasentin).

A comparison of the two groups revealed that the incidence of retention of any degree decreased from 35 per cent in Group 1 to 19 per cent in Group 2, and the incidence of serious retention (persisting longer than five days) from 24 to 13 per cent. In the first group six patients were subjected to secondary operation; in the second group there was no necessity for reoperation.

There is no single cause of postoperative gastric retention, so there can be no single remedy. The temperament, racial characteristics and emotional stability of the patient, as well as his economic and social stresses, are important. The size and position of the stoma, operative technic and preoperative and postoperative care are similarly important.

Regurgitant vomiting is of two general types: (1) The vomiting that develops immediately after operation suggests mechanical obstruction. (2) The vomiting that develops on the sixth to tenth day after operation occurs most probably because of stomal edema and inflammation. For the first type, some further operative procedure is frequently necessary; for the second type, supportive measures involving a knowledge of the principles of blood chemistry and fluid balance are usually sufficient.

Each surgeon should adopt an operative technic and a program of pre-operative and postoperative care that embody those principles which in his hands give good results. In our experience, the stoma is best made on the posterior wall of the stomach with the proximal loop of the jejunum attached near the lesser curvature at the level of the angle of the stomach. The stoma is made to run diagonally downward and to the patient's left toward the greater curvature. Three rows of suture should be used in the anastomosis, the third solely to allow careful approximation of the mucosal edges and to cover all denuded portions. The distal loop should be carefully replaced in the abdominal cavity to lie behind all other loops of bowel. If secondary operation is considered, jejunostomy alone is the procedure of choice, and is usually all that is necessary.

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# THE SO-CALLED "DUMPING SYNDROME" AFTER SUBTOTAL GASTRECTOMY

## A CLINICAL STUDY

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SINCE THE MIDDLE 1930's and much before this, especially in Europe, radical resection of the stomach has become increasingly popular as a method of treatment for certain complicated types of benign peptic ulcer. Coincident with the increasing frequency of performance of partial gastrectomy, gastroenterologists noted a corresponding increase in the number of patients who postoperatively exhibited vasomotor symptoms which comprise what is known as the "dumping syndrome."

## HISTORICAL REFERENCES

The literature regarding this topic is not voluminous. Apparently the first article in the English medical literature to refer to the condition was written by Hertz<sup>3</sup> in 1913. Mix,<sup>6</sup> in 1922, described what he termed a "dumping stomach." This diagnosis was made on the basis of roentgenologic findings; the typical symptoms were absent. In 1935, Eusterman and Balfour,<sup>1</sup> in their textbook on gastro-enterology, recognized the occurrence of this syndrome after simple gastro-enterostomy as well as after gastric resection. They stated, however, that the condition was so rare after well-indicated and properly performed gastro-enterostomy as scarcely to deserve mention. They ascribed its occurrence to distention of the upper jejunum, a view with which we agree. Snell,<sup>9</sup> in 1937, likewise, referred to this disturbance but also regarded it as "fortunately a rare complication" which occurs after gastro-jejunostomy either with or without resection. "In a few cases," he said, "symptoms appear after meals, but once the jejunum becomes accustomed to the new hook-up these tend to disappear."

In 1940, Glaessner<sup>2</sup> cited nine cases in which he thought the typical symp-

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Since this paper was written, Dr. Custer has entered the armed services and is now Capt., M.C., A.U.S.

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toms of the postgastrectomy, or dumping syndrome, were attributable to "hyperglycemic shock" related to sudden increase in the concentration of blood sugar as a result of rapid resorption of sugar by the jejunum. In 1942, Schwartz, Reingold and Necheles,<sup>7</sup> however, were unable to correlate the level of blood sugar with the appearance of symptoms and favored distention of the upper part of the small bowel as the underlying factor. They suggested that the distress could be aborted or lessened by the use of frequent small meals and by lying down

Jordan,<sup>4</sup> in 1941, recognized the syndrome in a discussion of the end-results of radical surgical procedures for peptic ulcer. She said that in cases in which partial gastrectomy had been performed anastomotic ulcers and the dumping syndrome accounted for 25 per cent of cases in which unsatisfactory results were obtained. Mateer,<sup>5</sup> in discussing Jordan's article, placed the incidence at about 14 per cent.

#### SYMPTOMS

The symptoms have been considered by some observers to be the result of hyperexcitability of the parasympathetic nervous system, or a manifestation of vagotonia. Other observers apparently have been disinclined to recognize the syndrome and have regarded the alleged symptoms as nonexistent or of functional origin. Physicians who have observed substantial numbers of these patients, however, either during their immediate hospital convalescence or during later consultation, do not doubt the presence of symptoms or the fact that they comprise definite clinical, or at least symptomatic entity.

The distress usually begins within the first 10 to 14 days after operation. It may and, as a matter of fact, frequently does, date from the first postoperative meal in which solid foods are included. Occasionally the onset may be delayed three to four weeks after operation and rarely six weeks.

The similarity of symptoms in these cases is astonishing, and they vary only in severity. The distress is entirely painless but is, nonetheless, disabling. It is invariably related to eating, and an attack may occur after every meal or only after an occasional one. For some reason, as yet unexplained, breakfast most frequently causes discomfort and several of our patients have experienced difficulty only after this meal. The size and nature of the feeding do not appear to be important factors, although approximately 20 per cent of our patients have implicated high carbohydrate foods, particularly rich desserts, as the precipitating factors.

The symptoms usually begin suddenly, either during the meal or within ten minutes afterward. The four cardinal, and almost invariable, symptoms are (1) profound nausea and weakness; (2) a generalized and unpleasant sense of warmth throughout the body; (3) a cold diaphoresis of the face, particularly of the forehead; and (4) cardiac palpitation. In severe cases there may be hypermotility of the small bowel with excessive borborygmus ending in explosive diarrhea. In milder cases diarrhea and vomiting are rare.

The attack, which usually lasts from 10 to 60 minutes, frequently can be prevented or relieved if the patient assumes the supine position. This method of securing relief is familiar to patients, as evidenced by the fact that "lying down" was almost the routine answer on a questionnaire in which we inquired: "What affords you the most relief?" One patient, whose symptoms persist in particularly severe form eight years after operation, remarked that she was feeling somewhat better but; "Who wouldn't, spending two-thirds of one's time lying down?"

#### PURPOSE OF STUDY

Observation of six patients who had been hospitalized for study and treatment of the typical dumping syndrome convinced us that this syndrome, which occurs, unaccountably after subtotal gastrectomy in certain cases, is composed of a well-patterned and closely related group of symptoms. Therefore, in June, 1942, a combined clinical and statistical investigation of this syndrome was undertaken to obtain information concerning its cause, incidence, prognosis, prevention and treatment. The foregoing topics will be discussed in consecutive order.

#### CAUSE

The sweating and palpitation that develop during an attack led us to speculate concerning the possible relationship between these symptoms and those of primary shock. However, a survey of the data in Table I disproves any etiologic relationship. Although a moderate rise in pulse rate ordinarily accompanies an attack, there is no other evidence of vasomotor collapse. The systolic blood pressure actually rises when the symptoms begin.

Vagotonia has been propounded as a causative factor in the production of the dumping syndrome. For this reason atropine sulfate was administered intravenously in amounts of 1/150 gr. (0.00043 Gm.) to four patients. Two injections were given to each patient on different occasions in an attempt either to block the attack or ameliorate the symptoms. The only effect noted was the customary parching of the mouth. Insofar as could be determined, the attacks were unaltered in duration and intensity.

Distention of the gastric remnant next was considered as a possible precipitating factor. However, deliberate overdistention of the remaining stomach by means of a balloon that had been attached to a nasal tube and then had been passed into the stomach failed to reproduce symptoms in two patients who were suffering daily from the typical dumping syndrome.

At the present time we are inclined to believe that the tendency of the stomach after subtotal gastrectomy to empty itself quickly, from which the dumping syndrome derives its name, is the chief causative factor. Sudden distention of the upper portion of the small bowel appears to be a trigger mechanism that initiates a widespread enteric reflex. This is characterized by nausea and excessive peristaltic activity, as evidenced by borborygmus,

“DUMPING SYNDROME”

TABLE I  
CLINICAL FINDINGS ASSOCIATED WITH DUMPING SYNDROME

	Pulse Rate, Per Minute	Blood Pressure, Mm. of Hg.
Before attack.....	72	110/60
During attack.....	80	100/55
Before attack.....	84	108/80
During attack.....	84	124/75
Before attack.....	76	105/75
During attack.....	80	115/80
Before attack.. ..	54	95/65
During attack.....	60	100/65
Before attack.....	80	125/80
During attack.....	84	140/76
Before attack.....	64	120/65
During attack.....	68	136/80
Before attack.....	72	105/65
During attack.....	80	118/70

TABLE II  
DUMPING SYNDROME AFTER SUBTOTAL GASTRECTOMY IN  
SERIES I AND SERIES II

Classification According to Severity of Symptoms	Cases	Per Cent
Series I (500 cases):		
Group A (mild).....	12	2.4
Group B (severe).....	10	2.0
Group C (disabling).....	6	1.2
Total.....	28	5.6
Series II (112 cases):		
Varying severity.....	14	12.5

TABLE III  
RESULTS IN TWENTY-EIGHT CASES FIVE YEARS OR LONGER AFTER SUBTOTAL GASTRECTOMY (SERIES I)

Classification According to Severity of Original Symptoms	No Reply	Status of Symptoms			
		Relieved	Mild but Persistent	Severe	Disabling
Group A (mild).....	2	3	4	3	0
Group B (severe).....	1	0	6	3	0
Group C (disabling).....	1	0	0	0	5

TABLE IV  
RESULTS IN FOURTEEN CASES FOUR TO TWELVE MONTHS AFTER  
SUBTOTAL GASTRECTOMY (SERIES II)

Type of Operation	Symptoms Continued	Symptoms Disappeared
Pólya.....	7	2
Shoemaker (Billroth-I)....	0	3
Hoffmeister (Pólya).....	0	2

and in severe cases, by violent diarrhea. We believe, moreover, that the development of this abnormal reflex is directly related to the size and type of gastro-enteric anastomosis. The puzzling fact remains, however, that on fluoroscopic examination after a barium meal practically all stomachs resected by the Pólya method empty rapidly; that is, within 15 to 30 minutes, and yet only a fraction of patients experience this annoying distress.

#### INCIDENCE

Since the postgastrectomy syndrome appeared from our study to be an important complication, determination of its exact incidence seemed essential. Consequently, the records of 500 consecutive cases encountered at the Mayo Clinic in which subtotal gastrectomy had been performed for benign peptic ulcer between January 1, 1935, and August 1, 1938, were studied carefully. These 500 cases subsequently will be referred to as Series I. Cases in which the symptoms were nonspecific or consisted of only indefinite postprandial nausea or indigestion were discarded. Only those cases in which the patients complained of typical nausea, weakness, warmth, sweating and palpitation with relief from lying down were selected. There were 28 such cases (5.6 per cent of 500), and they were divided into three groups according to severity of symptoms (Table II).

Group A (12 cases) was composed of patients who experienced typical symptoms but the symptoms were not sufficiently severe to interfere with normal activity. Group B (10 cases) was composed of patients who were sufficiently handicapped by postprandial distress to interfere with the performance of their daily work. Group C (6 cases) was composed of patients who were not only unable to work but also suffered more from gastric distress than they had prior to operation.

For the purpose of comparison, a smaller series of 112 recent consecutive cases (Series II) also was studied (Table II). In these cases subtotal gastrectomy for peptic ulcer with complications or for gastric malignancy had been performed by one of us (J. M. W.).<sup>10</sup> Dumping symptoms of varying severity occurred in 14 cases (12.5 per cent of 112). The higher incidence of the dumping syndrome in Series II than in Series I is attributable to the fact that since the surgeon was particularly interested in this syndrome, and since these patients came under our direct supervision, certain symptoms were recognized which might otherwise have been overlooked. In some cases typical postoperative symptoms are relieved within a few weeks, and since they are not regarded as significant, they may not be recorded by the physician unless he is particularly interested in this syndrome.

#### PROGNOSIS

The obvious question after a definite and appreciable incidence of the dumping syndrome had been established was: "What happens to these patients and to their symptoms?" The general practice has been to reassure these

patients concerning their symptoms, with the comment that within a few weeks or months "as the bowel adjusts itself to the new opening" distress gradually and spontaneously would subside.

The inaccuracy of this prophecy in many cases was apparent from a review of the cases in Series I. In numerous instances correspondence concerning continued distress was carried on for as long as five to eight years after operation. Thirteen of the 28 patients had considered the disturbance of sufficient importance to warrant one or more return visits to the clinic for consultation.

Consequently, on May 8, 1944, a questionnaire regarding the progress of symptoms was addressed to the 28 patients. The replies were discouraging since only three of the 24 patients who sent a report had had relief of symptoms. In these three cases (Group A), the symptoms always had been mild; in two cases the symptoms cleared up spontaneously in two years and in the third they disappeared three years after operation. The remaining 21 patients continued to have symptoms and, in most instances, the nature and severity of the distress were unchanged (Table III). In all cases operation had been performed between five and eight years previously.

#### PREVENTION

In 27 of the 28 cases in Series I, gastro-intestinal continuity had been restored after subtotal gastrectomy by means of a posterior Pólya-type of anastomosis. In the remaining case, a von Haberer modification of the Billroth-I operation had been performed. In our opinion, this high incidence of dumping syndrome after the posterior Pólya-type of anastomosis does not, in itself, incriminate this operation. In recent years this technic has been preferred at the clinic over all others and was employed in approximately 90 per cent of the 500 resections in Series I.

Nevertheless, we have surmised for some time that if the symptoms that we have described result from rapid dumping of a large bolus of food into the unprepared jejunum or duodenum, then the development of these symptoms may be directly related to the size of the new stoma. In the Pólya operation the stump of the stomach is anastomosed to the bowel and the resulting stoma is the width between the two curvatures. If the dumping syndrome is related to the size of the stoma, then the obvious solution should be an operation that narrows the gastric stump and, thus, provides a smaller gastrojejunal opening. Numerous procedures have been devised to accomplish this purpose, among them the Hoffmeister modification of the Pólya operation and the Shoemaker modification of the Billroth-I technic.

Approximately 15 months prior to preparation of this report, further study of this premise was undertaken. At first the results of the Hoffmeister modification of the Pólya operation and the Shoemaker modification of the Billroth-I operation seemed disappointing since typical symptoms, although always in a mild form, developed while the patients were still in the hospital.

Before long, however, we became aware of the fact that the symptoms were not only mild but also were transient. The Hoffmeister and the Shoemaker modifications were performed in 28 and 37 cases, respectively, and in no case did the dumping syndrome last longer than three weeks. Thirty-two of these cases are included in Series II. Of the 14 cases in which the dumping syndrome developed, only seven patients reported persistent symptoms when questioned by letter on May 8, 1944; these seven patients all had undergone a posterior Pólya anastomosis (Table IV).

In order to illustrate the foregoing discussion, three cases are presented. In Cases 1 and 2 (Series II) a severe dumping syndrome had followed gastro-enterostomy. After the Hoffmeister modification of the Pólya operation was performed in Case 1 and the Shoemaker modification of the Billroth-I operation in Case 2, the results were good. These cases are in contrast to Case 3 (Series I) in which a posterior Pólya anastomosis was performed.

#### REPORT OF CASES

**Case 1.**—A farmer, age 53, described a typical dumping syndrome which had occurred while he was still in the hospital after simple gastro-enterostomy performed in May, 1940. The symptoms had necessitated bed rest for an hour after every meal for the next two years and two months, and then unaccountably had subsided promptly with reappearance of the old ulcer distress.

Fluoroscopic examination at the Clinic revealed an anastomotic ulcer. The medical consultant expressed the opinion that reoperation was indicated but advised against a Pólya anastomosis because of the history of a dumping syndrome.

On March 7, 1944, a large gastrojejunal ulcer and the distal three-fifths of the stomach were resected. Continuity was restored by means of an anterior Hoffmeister type of anastomosis. The stoma, which purposely was made small, measured barely 1.5 inches (3.81 cm.) in diameter. The patient made an uneventful recovery, without once experiencing symptoms of rapid emptying of the stomach.

**Case 2.**—A housewife, age 44, reported that she had undergone gastro-enterostomy for duodenal ulcer in September, 1942. A definite dumping syndrome developed within the first week and persisted until reexploration was undertaken on March 4, 1944, because of jejunal ulceration. The stomach was disconnected from the intestine and the distal three-fifths of the stomach was resected. A Billroth-I anastomosis was effected, using the Shoemaker modification. On the thirteenth postoperative day mild dumping symptoms appeared and lasted several days. Improvement occurred after the administration of dilute hydrochloric acid. When the patient was dismissed on March 27, three weeks and two days after operation, she was entirely free from symptoms.

**Case 3.**—A man, age 20, related that he had undergone gastro-enterostomy in 1934. A dumping syndrome developed during the early postoperative period and persisted for the next two and one-half years. He came to the Clinic because of recurrence of pain which was found to be on the basis of marked gastrojejunitis. The medical consultant recommended that the stomach be disconnected from the intestine but advised against resection because of the dumping phenomenon. However, in view of the marked inflammatory reaction encountered in the stomach at operation, resection of the lower half of this organ seemed advisable and a posterior Pólya anastomosis was made. A severe type of dumping syndrome (Group C) promptly developed; this has practically incapacitated him from the standpoint of performing any work. Recently he has been undergoing syncope during some of the attacks.

#### TREATMENT

Treatment of the dumping syndrome is a difficult problem. Few, if any,

patients can be completely relieved. In perhaps half the cases substantial improvement occurs with reduction of the frequency as well as the severity of attacks. We use the following measures, either singly or in combination: 1. Patients are advised to lie down after meals. Breakfast in bed may be beneficial. 2. Ephedrine,  $\frac{3}{8}$  gr. (0.024 Gm.) with two or three soda crackers before meals can be used. 3. An ounce of cream or an ounce and a half of olive oil can be taken at the beginning of each meal. Fats, acids and alkalies tend to delay the emptying time of both resected and unresected stomachs. 4. Six small feedings daily instead of the customary three meals may be helpful. A dry diet which eliminates milk and milk products sometimes relieves distress. Sweets may cause distress. 5. Ten to 12 drops of dilute hydrochloric acid in a third of a glass of water may be sipped through a straw 30 minutes before meals.

Of these measures, the most encouraging results recently have occurred after the use of hydrochloric acid. We were led to try it after demonstration by Shay and Gershon-Cohen<sup>8</sup> that, whereas, the resected stomach usually emptied completely in 15 minutes, the addition of hydrochloric acid to a bariuminized meal produced a 50 per cent gastric residue after 60 minutes.

Of the 28 cases of dumping stomach encountered in Series I, 18 had post-operative studies of gastric acidity. In two of these cases low values for free acid were present after the test meal; that is 16 and 18 units, respectively. In the remaining 16 cases there was no hydrochloric acid response to the test meal. Two of these patients also were tested with histamine and found to have an histamine anacidity. Other drugs that have proved ineffective include atropine, insulin, *alpha* hypophamine and stilbestrol.

#### SUMMARY AND CONCLUSIONS

The dumping syndrome is a definite clinical, and probably physiologic, entity that occurs after gastro-enterostomy, either with or without gastric resection. It follows gastric resection in 5 to 12 per cent of cases. Since it apparently results from rapid dumping of food from the stomach into the unprepared jejunum, it is well named. When rapid dumping once has become established, it is apt to be permanent, since it probably is related directly to the size of the anastomotic stoma.

The results of operations that narrow the opening of the gastric remnant have been uniformly good; however, our series is still too small to insist, categorically, that this solves the entire problem. Reoperation for the dumping syndrome has not been undertaken but this is a procedure to be considered in some of the severe cases. The administration of dilute hydrochloric acid is of value in some cases. We believe, however, that prevention of the disturbance will prove more effective than its treatment.

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# POSTAPPENDICECTOMY INTERSTITIAL INGUINAL HERNIA

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FAILURE to recognize anatomic relationships at the primary operation is an important factor in the recurrence of inguinal herniation. From July 6, 1942 to February 8, 1945, 369 right inguinal herniae were repaired on the Surgical Service at Brooke General Hospital. Of these, eight, or 2.4%, presented an unusual surgical finding. In each of these cases successful repair depended on the recognition of the existing relationships at operation. One of them, Case 3, had previously been operated upon unsuccessfully, with a persistence of the original hernia.

In 1911, Hoguet<sup>1</sup> called attention to the frequent occurrence of right inguinal hernia following appendectomy with drained wounds. Many of these had not only a right inguinal hernia but an associated postoperative hernia at the site of the appendectomy scar. Hoguet, and Watson<sup>2</sup> attributed the occurrence of the hernia to a weakening of the abdominal wall following injury to the ilio-inguinal and ilio-hypogastric nerves.

All of the herniae to be presented were right-sided and followed appendectomy (Fig. 1). The interval between the appendectomy and the discovery of the hernia varied from four to 27 years. They were classified clinically by all examining surgeons as inguinal herniae. In each instance there was an easily reducible bulging mass at the external inguinal ring which descended on coughing or straining. An associated McBurney scar was always present.

At operation, the findings were at variance with the clinical diagnosis. The usual oblique hernia incision was made. The region of the McBurney scar was avoided because of the surrounding scar tissue. On dividing the fascial covering of the cord, fat, resembling omentum, was identified (Figs. 2 and 3). This was separated in each instance by sharp dissection from the vessels, the vas deferens and adjacent connective tissue. No peritoneal sac could be found. The omentum was traced to its point of origin, a peritoneal defect at the site of the original McBurney incision (Figs. 5 and 6). In order to properly expose this defect it was necessary to divide the internal oblique and transversus abdominis muscles (Fig. 4). After the omentum had been separated from the parietal peritoneum, the inguinal region was carefully explored from within the abdomen. With one exception no inguinal hernia was found. (In Case 6 an associated, indirect, inguinal hernia was discovered). Following the careful exploration of the inguinal region the peritoneal defect was closed with interrupted cotton sutures (Fig. 7). The transversus abdominis and internal oblique muscles were approximated with interrupted, stainless steel, wire sutures (Fig. 8). A modified Bassini type of repair was then employed in reconstructing the inguinal region.

In the postoperative period the patients were uniformly treated with bed rest for 14 days. After this they were allowed unrestricted ambulation.

The results were excellent in the five cases which could be followed. No recurrences were reported in a varying period of three months to three years interval since operation. All of them are engaged in active physical labor.

Particular attention is directed to this bizarre type of hernia for the following reasons: (1) The frequency of its occurrence. (2) It is a complication of poorly closed, drained, or secondarily infected appendectomy wounds. (3) Lack of recognition of the type of hernia present accounted for a pre-



FIG. 1.—Photograph of the abdomen (Case 1), taken postoperatively, showing relationship of the McBurney scar to the incision for inguinal herniorrhaphy. The black dots are situated over the anterior superior spine of the ileum and the pubic tubercle.

vious failure of repair in one of the cases. (4) To emphasize the necessity of opening the peritoneal cavity in each inguinal hernia and of exploring the inguinal region carefully.

**Case 1.**—A white male, age 51, was admitted to the hospital, February 18, 1945, with a diagnosis of right, indirect, inguinal hernia (Fig. 1). Previous surgery consisted of an appendectomy in 1917 for a ruptured appendix and a resection of the transverse colon in 1938 for carcinoma. He had first noticed a swelling in the "right groin" one year prior to admission. This had been symptomatic for the past two months only. During

this period he complained of intermittent, sharp and aching pain on standing or walking for short distances. The swelling had grown larger during the previous few months.

Physical examination revealed a pendulous abdomen. There was no tenderness or palpable masses. A small ventral hernia was present at the site of the previous colostomy. No herniation could be demonstrated at the site of the old appendectomy scar. There was an enlarged external inguinal ring on the right through which protruded a well-defined mass which increased in size on coughing or sneezing.

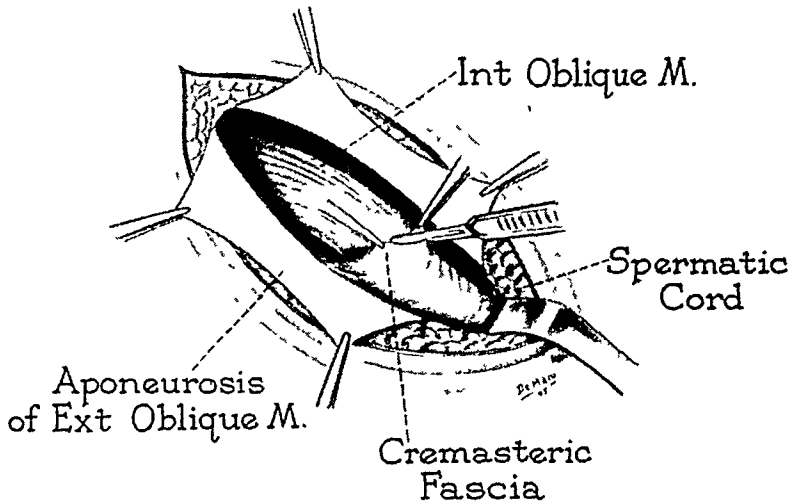


FIG. 2.—Diagram of the inguinal region before dividing the fascial covering of the spermatic cord.

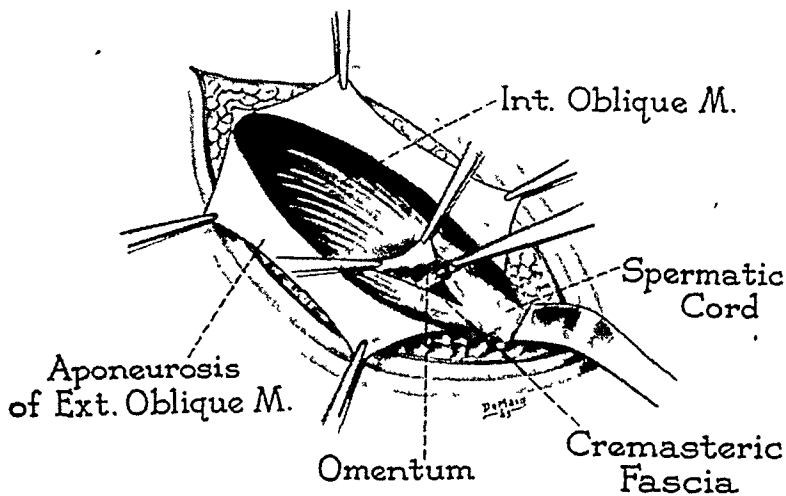


FIG. 3.—Diagram showing omentum within the cord. This is anchored above and extends below the opening to the region of the external inguinal ring.

At operation, February 24, 1945, the usual incision for the repair of a hernia was made. On incising the fascial coverings of the cord no peritoneal sac could be identified. Omentum adherent to the structures of the cord, however, was found to originate at a peritoneal defect of the old McBurney incision. The internal oblique muscle above the internal inguinal ring was divided to improve the exposure. Having dissected the omentum from the parietal peritoneum it was restored to its normal position within the abdomen. The entire inguinal region was explored from within the abdomen. No

hernial sac, either direct or indirect, could be demonstrated. The retracted peritoneal edges and transversalis fascia were mobilized and approximated with interrupted cotton sutures. The internal oblique muscle was sutured with interrupted wire sutures. A modified Bassini type of repair was employed in reconstructing the inguinal region. This man was discharged in excellent condition March 10, 1945. He is now employed, three months later, at farm labor.

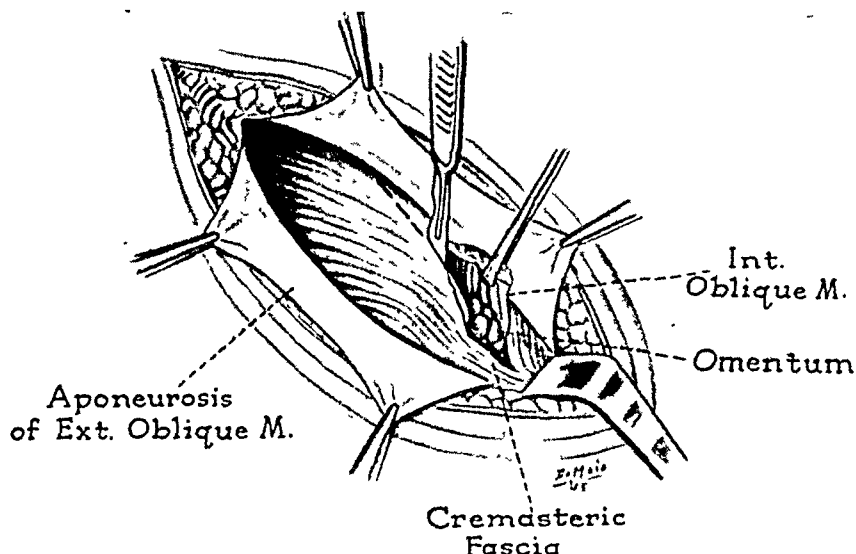


FIG. 4.—Diagram showing the internal oblique and transversus abdominis muscles divided. This improved the exposure of the peritoneal defect above and medial to the line of the inguinal incision.

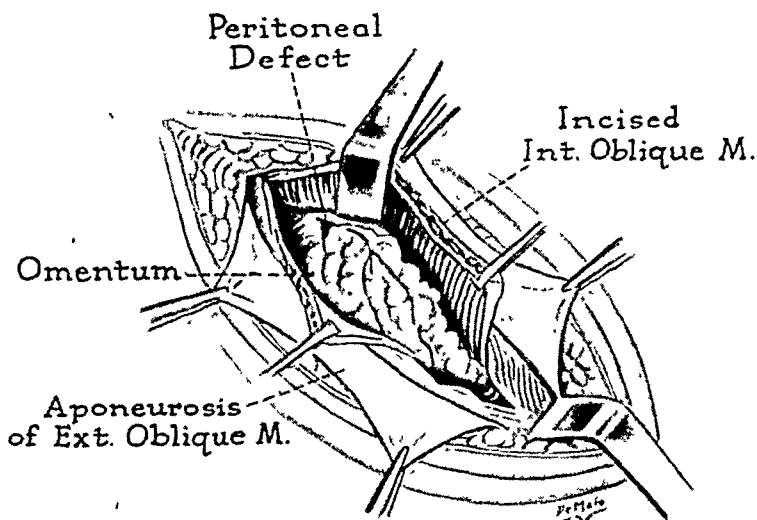


FIG. 5.—Diagram showing the omentum protruding through the peritoneal defect and extending down into the inguinal canal.

**Case 2.**—A 26-year-old white male was admitted to the hospital, February 17, 1942, with a diagnosis of a right, complete, indirect, reducible hernia. Previous surgery consisted of an appendectomy in 1921. One day prior to admission to the hospital the

presence of a hernia was discovered on routine physical examination. He had had no previous symptoms.

On physical examination the abdomen was found to be soft and obese. An ancient, right McBurney scar was present, with no evidence of herniation. A small, right, complete, indirect, inguinal hernia could be felt.

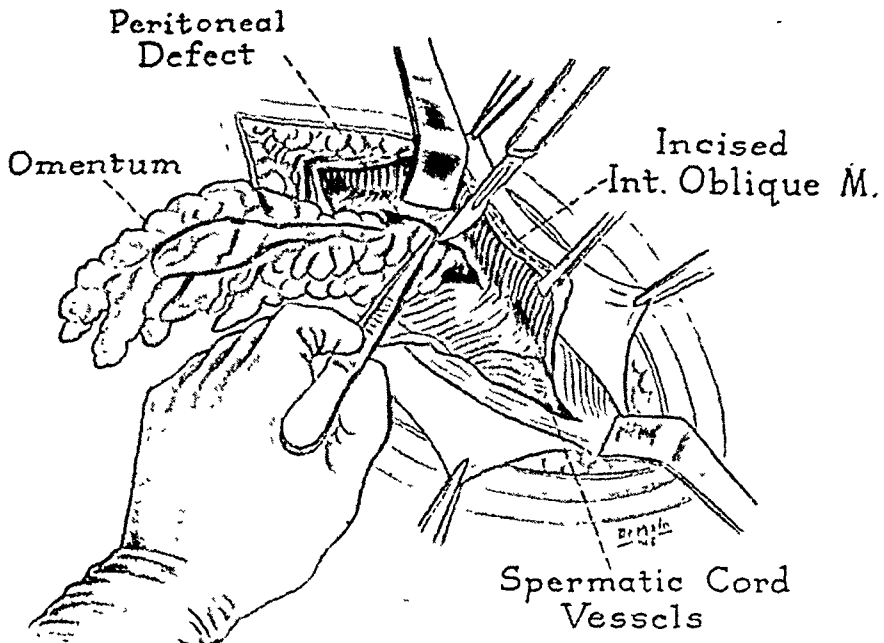


FIG. 6.—Diagram illustrating the dissection of the omentum from the parietal peritoneum in the region of the defect.

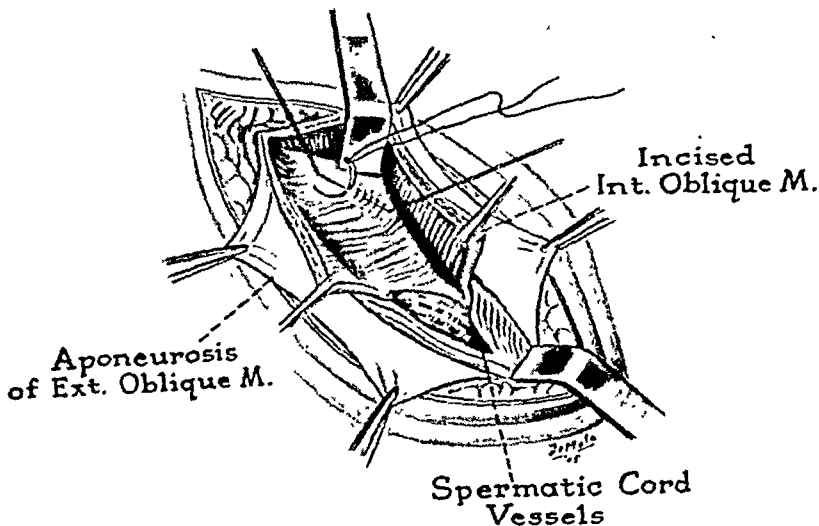


FIG. 7.—Diagram demonstrating closure of the peritoneum and transversalis fascia with interrupted cotton sutures.

At operation, February 19, 1942, the usual incision for an inguinal hernioplasty was made. On incising the fascial coverings of the cord no peritoneal sac could be identified. Omentum was found to be adherent to the cord structures. The origin of the omentum was a peritoneal defect at the site of the previous appendicectomy incision. The internal oblique muscle was incised in order to secure better exposure. The omentum was freed from the parietal peritoneum. The inguinal region was explored from within the abdomen and no hernia found. The peritoneal edges were approximated with interrupted

cotton sutures. A modified Bassini operation was used in reconstructing the inguinal region.

The postoperative course was uneventful, and the man was allowed out of bed on the 14th postoperative day.

Since operation he has had no pain or discomfort. He has passed all of the physical examinations for Air Corps personnel overseas, where he is now assigned.

**Case 3.**—A white male, age 24, was admitted to the hospital, October 6, 1942, with a diagnosis of right, complete, indirect, recurrent, inguinal hernia. Previous surgery consisted of an appendectomy (year unknown) and a right inguinal herniorrhaphy October 8, 1941. Following the previous repair of the right inguinal hernia he had no further symptoms until he developed a cough two months prior to his admission to the hospital. At this time he noted a recurrence of the herniation.

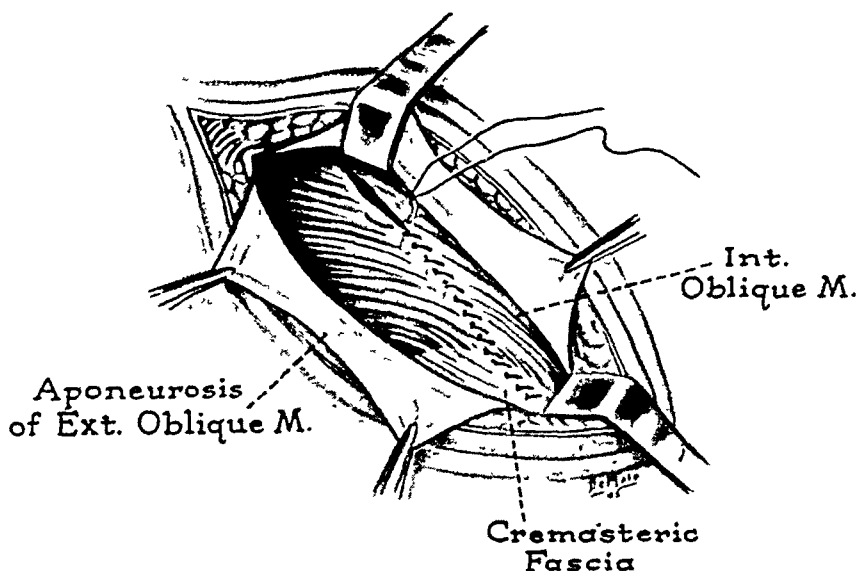


FIG. 8.—Diagram showing approximation of the divided edges of the internal oblique muscle.

On physical examination, an ancient herniorrhaphy scar was noted on the right side. Above and medial to the upper end of this was an old McBurney scar. There was no evidence of herniation at the site of the previous appendectomy incision. There was a definite, reducible, inguinal mass in the right side, with an enlarged external ring.

At operation, October 8, 1942, the usual oblique incision was made excising the skin cicatrix. On incising the fascial layers of the cord, omentum was found to be adherent to the surrounding structures. The omentum was freed by sharp dissection and traced to a defect in the peritoneum up under the internal oblique and transversus abdominis muscles. These were divided to secure better exposure, and the peritoneal defect was found to exist at the site of the previous appendectomy wound. The peritoneal cavity was explored in the inguinal region. No hernial sac, either direct or indirect, was found. The peritoneum and muscular layers were approximated separately. A modified Bassini procedure was used to strengthen the wall in the region of the internal inguinal ring.

The postoperative course was uneventful, and the man was discharged after a period of reconditioning on November 13, 1942. Since his operation this man has had no complaints and is now performing full duty with an Air Force Ground Crew overseas.

**Case 4.**—A white male, age 22, was admitted to the hospital, September 18, 1943, with a diagnosis of right, indirect, complete, reducible, inguinal hernia. He had had an appendicectomy in 1935. Six months prior to admission to the hospital, while lifting some heavy trays, the patient first noted pain in the right inguinal region. The pain was followed by a bulging or lump in the same area and the associated symptoms appear when he strains, lifts heavy objects or walks for a long period of time. Since appendicectomy in 1935 he has noted some pain at the site of the old McBurney incision.

Physical examination revealed a soft, well-healed, right, McBurney scar. There was a bulging in the region of the right, external, inguinal ring which expanded on coughing or straining. A diagnosis of right, indirect, inguinal hernia was made.

At operation, September 20, 1943, the spermatic cord was exposed through the usual inguinal incision. The fascial covering of the cord was divided. No peritoneal sac could be demonstrated but omentum was found to be adherent to the surrounding structures. The separated omentum was found to arise through a defect in the peritoneum at the site of the old McBurney incision. The internal oblique muscle was divided as in the other cases, the peritoneum closed, and a modified Bassini type of herniorrhaphy used in reconstructing the inguinal region.

After a period of reconditioning he was discharged from the hospital to full duty December 4, 1943. April 1, 1945 he was overseas in the combat zone engaged in the building of bridges. He has no complaints.

**Case 5.**—A white male, age 21, was admitted to the hospital, July 6, 1942, with a diagnosis of right, complete, indirect, inguinal hernia. Previous surgery consisted of an appendicectomy in 1935. The hernia was first noted on examination two weeks prior to hospitalization. This had been asymptomatic, and the man was not aware of its presence previously.

Physical examination: He was obese; the abdominal wall was thick and pendulous. There was no evidence of a herniation at the site of the previous appendicectomy. A right, indirect, reducible, inguinal hernia was present. This hernia extended down into the scrotum. All of the examining surgeons agreed that this was a perfectly typical inguinal hernia.

An operation was performed July 7, 1942. On incising the fascia of the cord, adherent omentum was encountered within. The source of the omentum was a defect in the peritoneum at the site of the previous appendicectomy incision. The internal oblique and transversus abdominis muscles were incised to secure better exposure. The omentum was dissected from the parietal peritoneum and the extraperitoneal portion excised. The inguinal region was explored for other herniations; none could be found. The peritoneal cavity was closed and the inguinal region reconstructed, using a modified Bassini procedure.

This man was discharged to full duty on August 12, 1942. He is still in the army, but we were unable to contact him concerning his present condition.

**Case 6.**—A white male, age 22, was admitted to Brooke General Hospital, August 12, 1944, with a diagnosis of right, inguinal hernia. He had had an appendicectomy in 1940. April 15, 1944, in Italy, while lifting some pipe, he noticed a sticking pain in the right inguinal region. Since that time a "knot" appears in that location if he lifts a heavy object or stands in one place for any period of time. There had also been a considerable amount of associated discomfort in this region.

Physical examination: There is an ancient oblique scar low in the right lower quadrant of the abdomen; no herniation is demonstrated at this site. A right, indirect, inguinal hernia was also present.



At operation, August 14, 1944, the usual hernia incision was employed. On opening the external oblique fascia, adhesions of this fascia to the internal oblique muscle and anterior sheath of the rectus muscle were encountered in the region of the old McBurney scar. This was located just above the inguinal incision. An indirect sac was found and opened. A defect in the peritoneum at the internal inguinal ring extended up into the abdomen. Through this defect omentum protruded extending down along the indirect hernial sac in an extraperitoneal location. The internal oblique muscle was incised to secure better exposure. The omentum was freed from surrounding structures. The peritoneal defect was closed above internal ring. A purse-string suture was then utilized to obliterate the indirect sac. A modified Bassini type of closure was employed in reconstructing the inguinal region. Following a period of rehabilitation this man was discharged from the hospital. He has had no complaints since operation. He was discharged from the Army for an unrelated condition and is now employed in farm labor.

Cases 7 and 8.—These clinical histories could not be obtained.

#### SUMMARY

A postoperative hernia arising in a McBurney incision is described. The hernia is characterized by a bulging at the external inguinal ring identical to that of a typical inguinal hernia. The fascia at the site of the McBurney scar is intact. The abdominal contents (in this series, omentum) courses through a defect in the peritoneum at the McBurney incision, finds its way under the transversus abdominis and internal oblique muscles to the inguinal canal. Transversing the inguinal canal, the omentum presents as a mass at the external inguinal ring, giving the impression of an inguinal hernia.

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## ANEURYSM OF HEPATIC ARTERY

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ANEURYSM OF THE HEPATIC ARTERY presents an unusual and exceedingly difficult diagnostic problem. The case herein reported, in which the diagnosis was established at operation and confirmed by autopsy after rupture of the aneurysm, is a typical and illustrative example. This aneurysm of the hepatic artery, and like the majority of such aneurysms, is considered to have been the sequela of an infectious process.

**Case Report.**—H. H. F., white, male, age 44, an insurance agent by occupation, was admitted to the hospital for diagnosis and treatment. The chief complaint was shortness of breath.

*Family History:* The patient's father, age 73, his mother, age 67, and two sisters and one brother were living and well. There was no history of the occurrence of mental disease, tuberculosis or cancer.

*Past History:* The patient had measles and mumps in childhood. He considered his health excellent at the time of enlistment in the army. He stated that while in the service he developed typhoid fever, complicated by influenza and pneumonia.

He was critically ill for a long time, and during convalescence was told that his heart was damaged—a leakage of the mitral valve. He received a discharge from the Service, November 28, 1917, because of cardiac disability.

In 1929, he was operated upon for ruptured appendix. There was no definite history of rheumatic fever, severe tonsillitis, diphtheria, scarlet fever or erysipelas. The patient denied any history of venereal disease. He denied the use of drugs. He used alcohol occasionally, and smoked moderately.

*Present Illness:* Following discharge from the army the patient had more or less difficulty with his heart, requiring rest periods at intervals.

For the past 15 years there had been shortness of breath on exertion, with a definite lessening of effort-tolerance during the past five years. During this time there had been evidence of pulmonary congestion, occasional palpitation and dull precordial pain. Blood-streaked sputum was noted on a number of occasions. However, there had been no occurrence of marked congestive failure.

Since the appendectomy, in 1929, the patient had had periodic attacks of gas and distention, associated with marked constipation. Dull pain and tenderness were occasionally present in the right upper and lower quadrants of the abdomen.

The patient stated that six months before his present illness he had an attack of what he considered to be influenza, with a severe cough, prolonged fever, sore throat and marked prostration. He had remained in bed to the time of present admission to the hospital.

The temperature had been normal in the mornings, but rose to 103.6° F. in afternoons. There were no definite chills. During this time there was some abdominal distress, but nausea or vomiting were not experienced.

Two weeks prior to admission the patient noted red spots, which he thought were blood blisters, on his legs. These disappeared in about ten days, leaving a brown discoloration.

*Physical Examination:* The patient was a tall, slender, undernourished adult white male, well-orientated and coöperative. He showed a moderate pallor. He was lying in bed without respiratory distress.

Height was 72 inches; his weight was 156 pounds. Eyes and mouth were negative. The cervical veins of the neck were slightly distended. The lungs were negative. The peripheral vessels were soft and compressible. The apex impulse was diffuse and heaving. On percussion, the left border of the heart was 14 cm. from the midsternal line in the sixth interspace. The right border was percussed 4 cm. from the midsternal line in the third, fourth and fifth interspaces. The sounds were irregular in force, rate, and rhythm. The first mitral sound was accentuated, and booming in quality. There was a harsh crescendo presystolic rumble, which was followed by a high-pitched systolic murmur. There was a slight systolic murmur over the aortic valve. The pulmonic second was accentuated. Pulse rate 100. Blood pressure 100/90. There was slight tenderness in the lower right quadrant of the abdomen, beneath an appendectomy scar. There was also slight tenderness over the liver area. The liver was palpable at the costal margin.

The spleen was not palpable and no masses were noted. The genitalia and rectum disclosed no abnormalities.

The skin showed no evidences of fresh petechiae, but there were a few scattered faint pigmented areas over the feet.

Neurologic examination disclosed nothing of interest.

*Admission Diagnosis:* (1) Rheumatic heart disease, with mitral stenosis; (2) cardiac enlargement, marked; and (3) auricular fibrillation.

*Laboratory Data:* The urine showed moderate albumin; few hyaline and granular casts, the specific gravity varied from 1005 to 1016; the P. S. P. 30; N. P. N. 30.4; the creatinin 1.6. The Wassermann reaction was negative.

The chest roentgenogram showed marked enlargement of the heart, with mild pulmonary congestion.

The electrocardiogram showed characteristic findings of auricular fibrillation.

Three blood counts were reported as negative. W. B. C. was 14,500, with 76 per cent polymorphonuclears. The R. B. C. was 5,300,000, hemoglobin 70 per cent; W. B. C. 14,000, 60 per cent polymorphonuclears.

*Clinical Course:* Following admission, the patient remained afebrile. He was put on a restricted diet, and was digitalized. He was ambulatory, without distress. Several days later he complained of severe pain in the epigastrium and upper quadrant. It had started with a dull ache the evening before, and continued through the night, becoming severe in the morning. Icterus of the sclerae was noted. Temperature was 101° F. The abdomen was extremely tender in the epigastrium and the right upper quadrant. There was definite localized rigidity in the right upper quadrant. At this time, the blood count showed W. B. C. 12,000, with 88 per cent polymorphonuclears. It was considered that the patient was suffering from an acute cholecystitis and cholelithiasis, with probable common duct stone. The patient stated that this distress was not unlike that which he had been suffering during the past few months, except that it was more severe.

The patient was treated conservatively. The pain continued, with frequent attacks of nausea and vomiting. Deep jaundice developed. A few days later a mass was felt below the liver edge, and was considered to be an enlarged gallbladder. Genito-urinary examination disclosed nothing significant. The Vandenberg test gave an immediate direct reaction. The total W. B. C. varied between 10,400 and 11,300. The polymorphonuclears varied from 80 to 88 per cent. An attempted biliary drainage gave no bile.

*Operation.*—Exploratory celiotomy: A slightly enlarged gallbladder was seen. The liver was moderately enlarged. A mass was seen posterior to the gallbladder and ducts, and extending posteriorly along the under surface of the liver. This mass was thickly covered with fibrin. Aspiration, with a small needle, showed arterial blood. The mass did not pulsate.

It was clear that the obstructive jaundice was due to compression of the ducts by this mass. Further operative procedure was considered inadvisable, due to the cardiac condition.

*Postoperative Course:* This was entirely satisfactory and uneventful until ten days later, when the patient suddenly complained of severe epigastric pain. He quickly went into shock, and died a few minutes later.

*Autopsy:* The subject was a fairly well-developed male, showing severe jaundice of the skin and sclerae. There was a recent right rectus surgical wound, and the abdomen was markedly distended. The abdominal cavity contained an enormous amount of dark red blood clot.

The mass which had previously been noted at operation was seen on the under side of the right lobe of the liver, just posterior to the gallbladder, and measured 8 cm. in diameter. It was somewhat fluctuant. A perforation was found in the posterior position of the mass which would admit the tip of the forefinger (Fig. 1).



FIG. 1.—Under surface of liver showing ruptured aneurysmal sac of the hepatic artery. The gallbladder has been dissected away.

On section, this mass was seen to be a large aneurysm, which contained laminated blood clot, causing the wall to be thickened to 2 cm. The center of the sac was filled with recent dark blood clot. Further examination showed that the mass was an aneurysm of the hepatic artery. Both the proximal and distal portions of the hepatic artery were identified.

Microscopic section showed that the wall of the aneurysm was composed of fibrous connective tissue, in which numerous small round cells were scattered. The inner surface showed organized blood clot. Section of the artery just proximal to the aneurysm showed no evidence of syphilis or arteriosclerosis.

The heart was enlarged, and weighed 500 Gm. There was dilatation of all chambers. There was marked hypertrophy of both ventricles. The right side of the heart was more dilated than the left. The mitral valve was thickened and fused, showing a typical

fish-mouth opening, 1 cm. long. Calcification was noted in the valve leaflets. The aorta showed a mild arteriosclerosis. The lungs and liver showed evidences of congestive heart failure.

*Anatomic Diagnoses:* (1) Aneurysm of the hepatic artery, ruptured, with massive hemorrhage into the peritoneal sac; (2) rheumatic heart disease, with mitral stenosis; (3) chronic passive congestion of the liver, lungs and spleen; and (4) jaundice.

*Frequency and Occurrence:* Rolland, in 1908, was able to collect 40 cases of aneurysm of the hepatic artery in the literature, and added one case.

Weiss, in 1921, was able to find 14 additional cases since Rolland's review, and added a case, making a total of 56 cases.

Friedenwald and Tannenbaum, in 1923, collected 65 cases of aneurysm of the hepatic artery from the literature, and described a case of their own.

Malloy and Jason, in 1942, reported a case of aneurysm of the hepatic artery, and collected from the literature 19 cases in addition to the series studied by Friedenwald and Tannenbaum.

*Etiology:* The etiologic factors concerned in the production of aneurysm of the hepatic artery are interesting because syphilis does not play the important rôle which it assumes in formation of aneurysms in general.

Weiss found that the majority of the recorded cases have followed acute infections, especially lobar pneumonia. In a series of 26 cases in which the etiology was determined with a fair degree of accuracy, 15 were associated with such conditions as pneumonia, osteomyelitis or typhoid; syphilis apparently was responsible for two cases; atheromatous aortitis, two cases; cholelithiasis, two cases; trauma, one case; and tuberculosis, one case.

Weiss noted that Schupfer reported a case of aneurysm of the hepatic artery following croupous pneumonia. He concluded that the aneurysm resulted from acute infectious arteritis produced by infectious agents transported in the vasa vasorum.

Grunert, according to Weiss, considered that 73 per cent of the 34 cases of aneurysm of the hepatic artery which he collected were to be interpreted as sequelae of infectious processes.

Aschner concluded that in his case the aneurysm was atherosclerotic in origin, the aorta and hepatic artery presenting advanced lesions of atherosclerosis.

In the series of 65 cases studied by Friedenwald and Tannenbaum definite causative factors were noted in 50 cases as follows: Generalized infection, seven cases; pneumonia, five cases; typhoid, two cases; pleurisy, with empyema, one case; osteomyelitis, three cases; arteriosclerosis, 12 cases; cholelithiasis, five cases; syphilis, seven cases; and trauma, eight cases.

Friedenwald and Tannenbaum say that trauma as an etiologic agent may act from without or from within, as by direct injury to the arterial wall by gallstones. They note that trauma was prominent in the case reported by Somner, in which the patient fell and injured the abdomen; Mester's patient was kicked in the abdomen by a horse; Brion's patient was subjected to frequent pressure on the abdomen with bars of iron during work.

Malloy and Jason found that infectious processes caused 41, or 60 per

cent of 68 cases of aneurysm of the hepatic artery, in which the cause was given. Next in frequency came arteriosclerosis (15 cases, or 22 per cent) and trauma (seven cases, or 10 per cent). Syphilis was not prominent in this series. Cholelithiasis was reported as the cause in five cases. Malloy and Jason think that the concomitant cholangitis is perhaps more important than the pressure caused by concretions. These authors add the thought that in cases wherein the lesion encroaches upon a passage of the digestive system, the intake of food and normal processes of digestion, may, as in this case, have been a factor in precipitating hemorrhage.

According to the study of Friedenwald and Tannenbaum, aneurysms of the hepatic artery are four times more common in males than in females. They found the age-range to be from 14 to 83 years, the average age in 63 cases being 38 years.

Malloy and Jason found a sex ratio of three males to one female in a series of 82 cases in which the sex was recorded (62 males, 20 females). They noted a wide age-distribution in this series, the youngest patient a ten-year-old boy, the oldest a man, age 83. The average age of occurrence was 38—for males 36, for females 42 years.

*Pathology:* Aneurysms of the hepatic artery have been divided into two groups: the extrahepatic and the intrahepatic. Friedenwald and Tannenbaum, in their study of 65 cases, found 45 extrahepatic and 18 intrahepatic, and two instances in which both intrahepatic and extrahepatic varieties were noted. In each of these two cases, the right branch of the hepatic artery presented an extrahepatic aneurysm while the left branch presented one of the intrahepatic variety. In 60 of this same series of 65 cases the main trunk was affected 29 times, the left branch six times, and the right branch 23 times, while in two instances the aneurysm was noted as a part of the cystic artery. In the case reported by Teacher and Jack, in a man, age 40, there was rupture of the left lobe of the liver caused by the bursting of an aneurysm of a small branch of the hepatic artery embedded deep in the liver tissue. The hepatic arteries were found to be the site of a widespread, patchy, subacute inflammatory condition. The cause of this condition was not clear, but the evidence was in favor of syphilis.

Malloy and Jason found in a series of 84 cases of aneurysm of the hepatic artery, in which the position is recorded, 61 were outside the liver, 20 were within the liver and three subjects had both intrahepatic and extrahepatic aneurysms. They add that while aneurysms of the hepatic artery are usually single in occurrence their series showed two aneurysms in six cases, three aneurysms in three cases, five aneurysms in one case, and "several" in one case.

Friedenwald and Tannenbaum, in their study of 65 cases, found that rupture of the aneurysmal sac occurred in 45 cases, while 13 remained unruptured. In 33 instances the rupture was into the abdominal cavity; in 21 the rupture was into the bile passages; in one, into the stomach; in two, into the duodenum; in one, into the portal vein. These authors note that in the case reported by Ledieu (1856), the ruptured aneurysm apparently underwent

spontaneous healing, being discovered in a patient who had died of renal disease. This aneurysm was occluded by a thrombus, and had produced no symptoms. In a similar case reported by Merkel, a thrombosed and calcified aneurysm of the hepatic artery, the size of an egg, was discovered incidentally at autopsy, and had produced no symptoms.

In the case reported by McCrae the aneurysm (2 x 3 cm.) was located at the bifurcation of the hepatic artery. In this case the thoracic aorta showed a dissecting aneurysm between the media and adventitia which extended for 16 cm. The inner surface of the aorta showed yellow nodular areas of degeneration suggestive of syphilis. In the left internal carotid there was a third aneurysm (7 x 4 cm.). The smaller arteries showed an extreme degree of obliterating endarteritis characteristic of syphilis.

Malloy and Jason say that the smaller aneurysms of the hepatic artery are usually true aneurysms resulting from dilatation of the vascular wall; the larger ones, however, are in part false aneurysms or hematomata resulting from rupture of the weakened vascular wall into the retroperitoneal tissues. Both true and false aneurysms become adhered to surrounding structures by dense fibrous adhesions and may cause compression of the bile ducts. Malloy and Jason add that eventually most of these aneurysms rupture either into the abdominal cavity or into some adjacent structure. Rupture occurred in 67 of the 85 cases they collected; 35 into the abdominal cavity; 22 into the extrahepatic bile ducts; seven into the duodenum; six into the gallbladder; one into the portal vein; one into the stomach.

*Symptoms and Diagnosis:* Teacher and Jack say that in some cases of aneurysm of the hepatic artery there have been no symptoms referable to the liver, the aneurysm proceeding to the rupture before its presence was suspected. Most authors agree, however, that in the majority of cases there are definite symptoms, the most common of which are pain, jaundice and hemorrhage (hematemesis and melena).

Malloy and Jason from their study of 85 collected cases found that aneurysms of the hepatic artery cause varied symptoms, but pain, hemorrhage, and jaundice occur with such frequency that they may be considered as aids in diagnosis. Pain (58 cases) was the most frequent symptom. It occurred in the right hypochondrium, the epigastrium or in both of these regions. Hemorrhage (40 cases) was next in the order of frequency, and occurred as profuse hematemesis or melena, or as occult blood in the stools. Repeated hemorrhage may cause severe secondary anemia. Jaundice (36 cases) was the third more constant symptom. It was usually of the obstructive type caused by compression of the common duct by the aneurysmal sac or rupture of the aneurysm into the duct causing obstruction by blood clot. The jaundice may be intermittent or persistent and severe.

According to Malloy and Jason less common symptoms are fever (noted especially in those cases associated with infectious processes) asthenia, headaches, constipation, and ascites. A pulsating tumor with systolic murmur and enlargement of the liver have been noted.

In Friedman's cases, paroxysms of pain were associated with a visible pulsation over the liver, accompanied by systolic shock felt over the ribs.

McCrae states that, in general, the striking clinical features of the reported cases of aneurysm of the hepatic artery have been pain, jaundice and hemorrhage into the digestive tract. The pain is paroxysmal, suggesting biliary colic. The hemorrhage is intermittent. Rupture into bile passages, stomach or duodenum is evidently present.

In cases which come to operation, diagnosis was not made after opening the abdomen in about half of the reported cases. McCrae says that in the majority of such cases, the condition has been diagnosed as ulcer or gall-bladder disease.

Riml discusses the differential diagnosis of aneurysm of the hepatic artery. He notes that gallstone colic, bleeding duodenal ulcer, papillary carcinoma, and liver metastases must be considered. He says that a bleeding liver metastasis which causes colic is the hardest condition to differentiate prior to exploratory celiotomy. He describes a case in which the prominent symptoms of aneurysm of hepatic artery (gallstone colic and melena) were present, and observation of the clinical course led to a diagnosis (later verified) of mycotic aneurysm of the hepatic artery caused by sepsis lenta.

*Treatment:* Weiss concludes from his study of the literature that under favorable circumstances the treatment of aneurysm of the hepatic artery is ligation of the artery.

Ashner says where the diagnosis is made at operation ligation of the hepatic artery should be done. This author says that according to Langenbuch, Kehr, and others, when the pathology of the hepatic artery is such as to lead to a slowly progressive diminution of the blood which it supplies to the liver (as in the case of aneurysm), the formation of a collateral circulation takes place by way of the inferior phrenic. It is this fact which makes possible ligation of the hepatic artery (as successfully done by Kehr) without ill effects on the liver.

McCrae suggests ligation when operation is possible, but notes that there is always danger of hepatic necrosis. He mentions two successful cases in the literature (Kehr, Anderson). Anderson's patient was operated upon after rupture of an aneurysm of a branch of the hepatic artery. He had been operated upon for an aneurysm of the radial artery previously and was operated upon later for an aneurysm of the tibial artery. This patient improved under specific therapy.

Friedenwald and Tannenbaum note that since the first successful ligation of the hepatic artery for aneurysm was done by Kehr in 1903, nine other cases have been subjected to surgery (Riedel, Grunert, Merkel, Allesandri, Tuffier, Friedman, Baruch, Anderson and Kading). Of this series three patients recovered (those of Friedman, Anderson, Kading). Of 13 cases recorded in the literature which were subjected to operation in only eight cases was the correct diagnosis made at operation.

Gordon-Taylor presents a case which he says is unique, in that it is the only recorded instance in which anything except ligation of the parent artery



has been attempted as a surgical measure. He says that at operation a "considerable button" of aneurysmal wall was left on the artery and a reconstructive aneurysmorrhaphy was performed. The remains of the hepatic artery were sutured in layers. He says that subsequent bacteriologic findings in the blood clot of the aneurysm precluded any final success from aneurysmorrhaphy in this particular patient, but in order such aneurysms which have a noninfective cause this method can hardly yield results more disastrous than those attending ligation. He feels that the difficulties of aneurysmorrhaphy are by no means as great as those of ligation, and that the method is worthy of consideration when the surgeon at operation is confronted with an aneurysm of the hepatic artery.

Gordon-Taylor adds that the results of ligature of the main hepatic artery for aneurysm appear to be worse than those attending ligature of this artery under other circumstances. He finds that in a series of ten collected cases of ligature of the hepatic artery for conditions other than aneurysm the mortality rate was 60 per cent; in a series of 12 cases of arterial ligation for aneurysm of the hepatic artery or its branches 75 per cent of the patients succumbed. In this series Gordon-Taylor says that in two of the three surviving patients there was no certainty that an aneurysm was present. He believes that Kehr's case is the only positive success in ligature of the hepatic artery for aneurysm.

Malloy and Jason feel that treatment of aneurysm of the hepatic artery, like that of aneurysms in general, is unsatisfactory. Ligation is dangerous, likely to result in death from liver necrosis or insufficiency. They offer the hope, however, that if the diagnosis can be established, the surgical approach "perhaps by gradual reduction of blood supply to the part and establishment of a collateral circulation" might lead to a larger percentage of cures. At the present, they feel that the prognosis is decidedly unfavorable.

#### SUMMARY

A case of ruptured aneurysm of the hepatic artery, occurring in a patient with rheumatic heart disease, is reported. It is considered that this case was of infectious origin since no gross or microscopic evidence of syphilis or arteriosclerotic changes were noted. A brief summary of the relevant literature is included.

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# REFLEX VASODILATATION IN TUBED PEDICLE SKIN GRAFTS

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AND

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TUBED PEDICLE SKIN GRAFTS, as well as other types of pedicled grafts, not infrequently give rise to concern over their blood supply. This may occur following the first stage, or after any subsequent shift, and in spite of following the rules of relation of length to width, time before shift, or size of new attachment. In an effort to improve early circulation, particularly where it appeared inadequate, use was made of reflex vasodilatation produced by immersing an hand and forearm, or leg and foot, in warm water. The following report is of an investigation undertaken in order to evaluate the effect on tubed pedicle skin grafts of such a procedure.

Learmonth<sup>1</sup>, in discussing the use of reflex dilatation in surgery, suggested it had wider application than was generally known, and specifically mentioned the improving of blood supply to skin grafts. The method used was that of Gibbon and Landis<sup>2</sup>, who were able to raise the temperature of the lower extremities by immersion of the forearms in hot water. A thermocouple was used to measure skin temperatures. Twenty-one studies were made on 14 patients.

Tubed pedicle skin grafts were labelled A, B, and C for the purposes of this investigation as follows: Type-A were those whose ends had never been detached (Fig. 1); type-B those having had one end transplanted (Fig. 2); and type-C those having had both ends transplanted (Fig. 3). Type-A had intact vessels and nerves entering at each end; type-B had intact vessels and nerves entering at one end only; and type-C had had vessels and nerves at each end divided to form, literally, denervated masses of tissues living parasite-like by means of a newly formed blood supply in a foreign site.

## METHOD OF STUDY

Areas to be examined were exposed for half an hour prior to the test, the patient lying quietly in bed. Surface temperatures were taken at three body sites, and at three sites on the graft every ten minutes during this period. Studies were begun when the temperature became stabilized. Mouth temperatures were taken during the first few experiments but, as no deviations from normal were noted, the practice was discontinued.

Next, one forearm and hand (or leg and foot) was immersed in a bath containing water at a temperature ranging between 42 and 47 degrees centigrade. This was continued for one-half hour, the bath being kept at a constant temperature. Temperature readings were taken as during the preliminary phase.

During the third half hour the patient lay quietly in bed as during the preparatory phase. Skin temperatures were again taken at the usual intervals.

The results are shown graphically in Graphs 1 to 14(b).

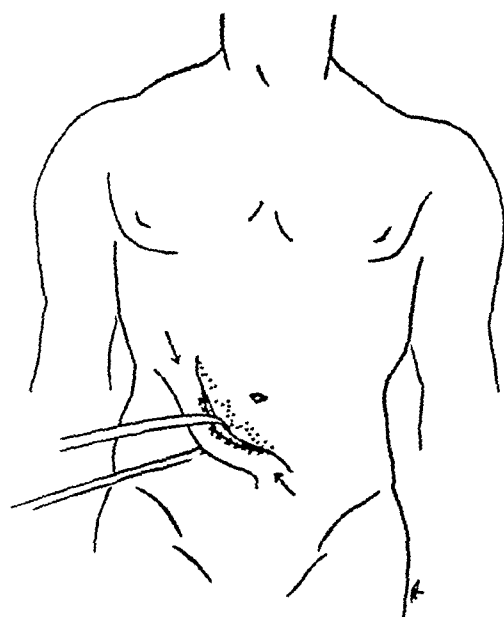


FIG. 1



FIG. 2

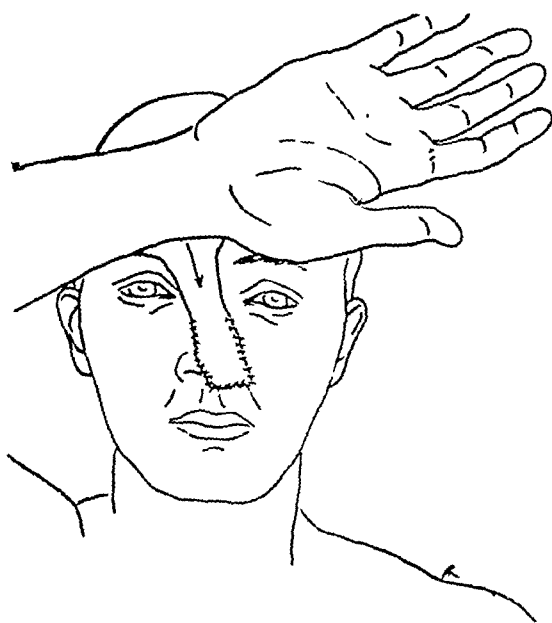


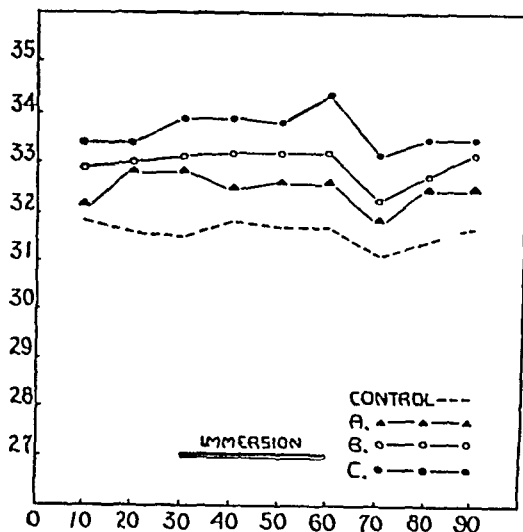
FIG. 3

FIG. 1.—Type-A Tube Graft: A tube of skin has been formed without interfering with the natural attachments at each end. The blood supply and nervous connections are uninterrupted.

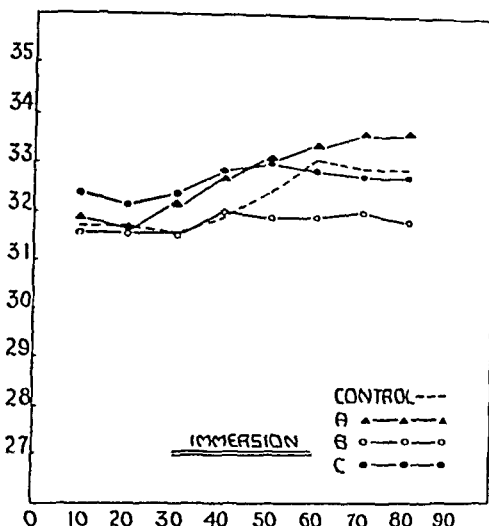
FIG. 2.—Type-B Tube Graft: One end of the type-A graft has been severed from its natural attachment and transplanted to a foster parent site. One natural attachment remains. One end is almost avascular immediately after operation, one set of nerves has been severed and one zone of inflammatory reaction and healing exists.

FIG. 3.—Type-C Tube Graft: The foster parent end having healed and vascularized sufficiently is able to take over the entire burden of supply and allow the natural end itself to be transplanted. These are denervated masses of tissue growing parasite-like through a newly formed blood supply in a foreign site.

SUMMARY OF RESULTS OF IMMERSION OF ONE LIMB SHOWN COMPARED TO ONE CONTROL AREA WITH SKIN TEMPERATURES IN DEGREES CENTIGRADE PLOTTED AGAINST TIME IN MINUTES. IMMERSION PERIOD IN EACH CASE LASTED FROM 30 MINUTES TO 60 MINUTES. (GRAPH I—XIV)



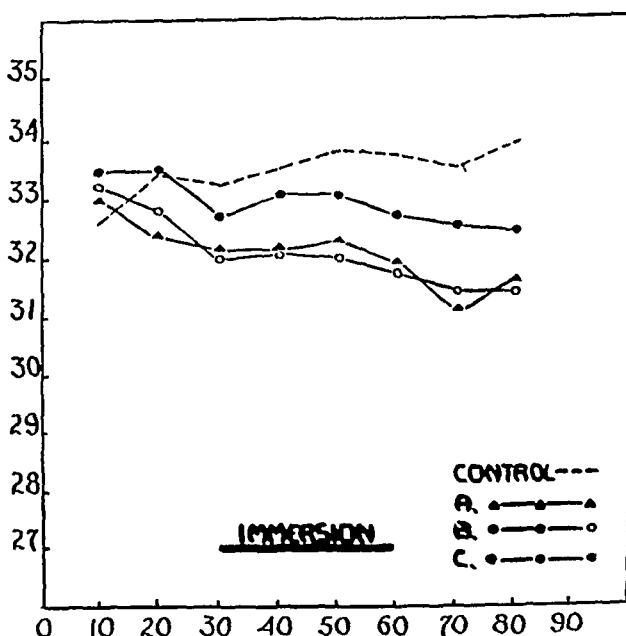
GRAPH 1



GRAPH 2

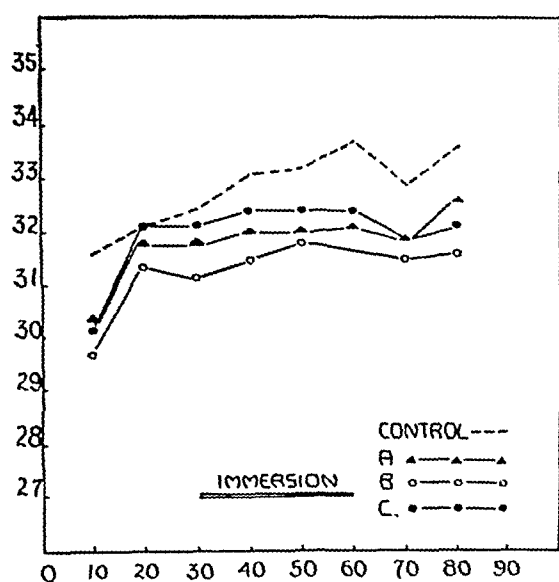
GRAPH 1.—A. E. B., a 28-year-old male, with 3.5-inch cervical tube (type-A) for reconstruction of ear—15 days postoperative. Tube appeared healthy, of good color but narrow and hard to study. Point C (lower end) apparently the main vascular supply showed only moderate response to peripheral dilatation. Sensation retained in tube. Control area—axilla.

GRAPH 2.—J. F., a 23-year-old female, with 3.5-inch x 5/8-inch cervical tube (type-A) for reconstruction of ear. Tube formed 16 days previously, with intermediate bridge which was divided 12 hours before study. Tube healthy color but reduced sensation over middle portion. Point A (lower end) alone showed slight vasodilator response. Control area—cheek.

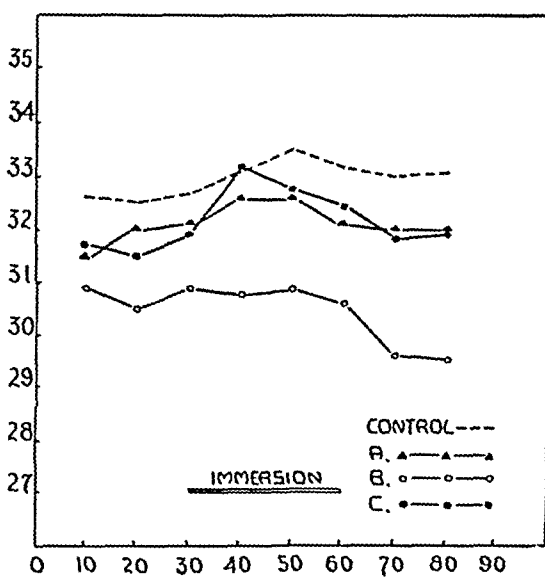


GRAPH 3.—Lieut. A. M., a 27-year-old male with five-inch abdominal tube (type-A) for grafting in defect of left hand—20 days postoperatively. Patient unusually sensitive to immersion bath. Has always sweated profusely—confirmed during examination. Patient remarked on feeling no body flush from immersion but felt pain at immersion site. Control area—cheek.

# VASODILATATION IN TUBED GRAFTS



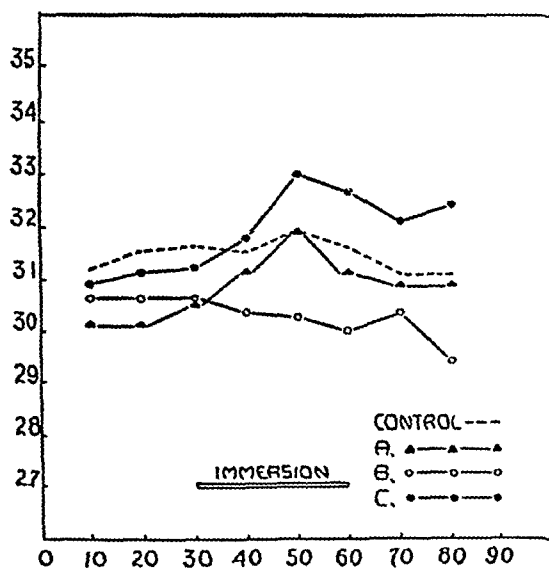
GRAPH 4A



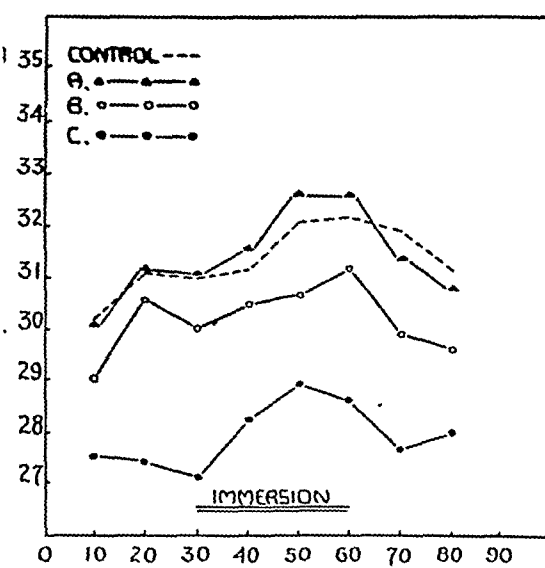
GRAPH 4B

GRAPH 4A.—Lieut. R. S., a 30-year-old male, with 4.5-inch abdominal tube (type A) for restoration of fleshy defect in hand—17 days postoperatively. Point C was lower end tube. Control area—cheek.

GRAPH 4B.—Lieut. R. S. (same patient as Graph 4), seen 12 hours after elongation of abdominal tube to nine inches (type-A). Point C again lower end (elongated end). Control area—cheek.



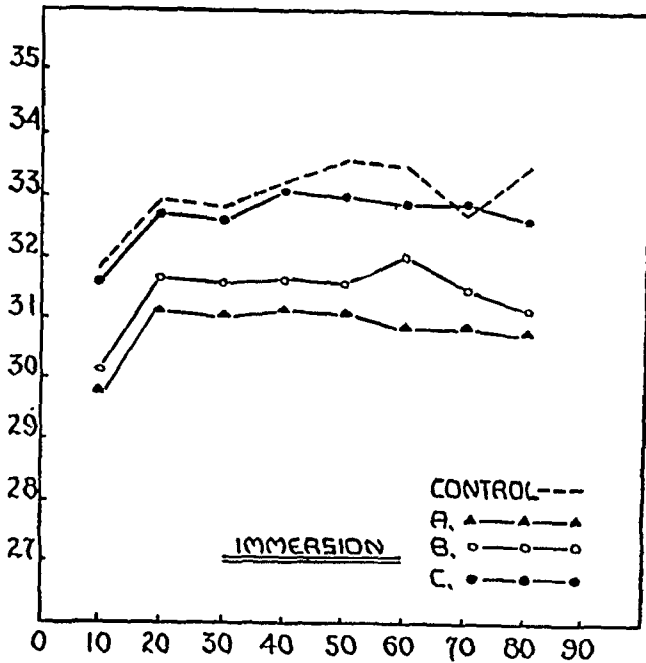
GRAPH 5A



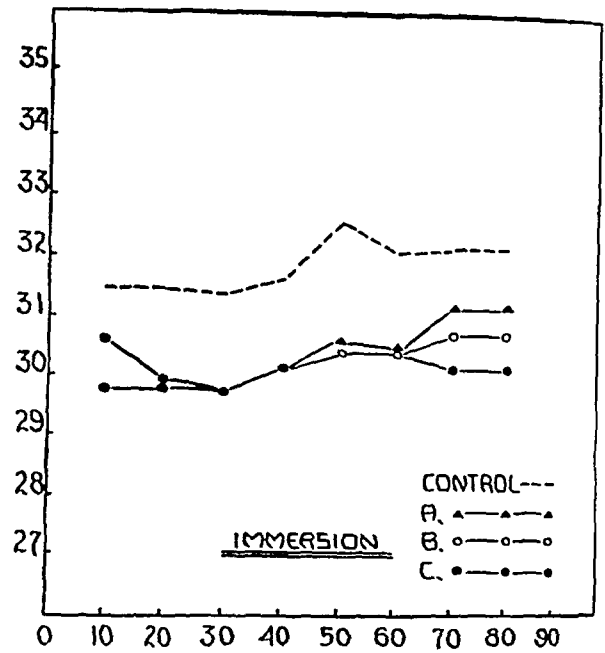
GRAPH 5B

GRAPH 5A.—A. G. H., a 26-year-old male with 9.5-inch abdominal tube (type-A) for restoration of popliteal defect, studied 22 days postoperatively. Tube of good color, warm, with rapid restoration of color after blanching under pressure. This tube had been lengthened in two stages to present length. Point C lower end tube. Control area—abdomen.

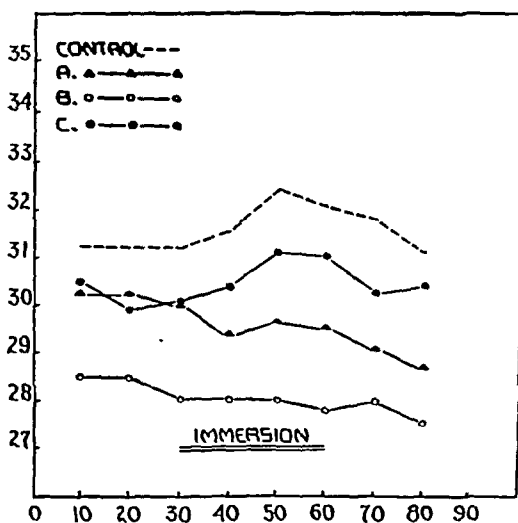
GRAPH 5B.—A. G. H. (same patient as Graph 5), examined 12 hours after upper end of tube had been transplanted to thigh. Point A on abdominal end. Point C on transplanted end in thigh. The lower half of the tube was bluish and cyanotic. During immersion this receded to the lower end and was barely visible at the conclusion. Type-B tube. Control area—cheek.



GRAPH 6.—M. G. R., a 22-year-old male, with nine-inch tube, originally formed on abdomen, now attached to right arm for final implantation on leg. Studied one week postoperatively. Type-B tube. Point C was abdominal end, Point A on arm end. Control area—cheek.

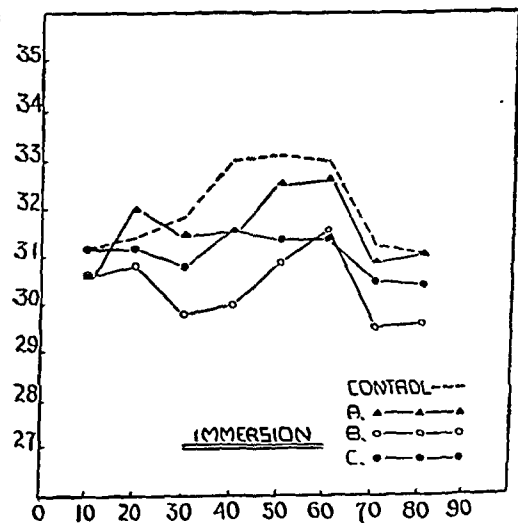


GRAPH 7.—Lieut. M. McC., a 32-year-old male, with pedicle flap from temporal region rotated to reform superciliary ridge overlying cancellous bone graft. Seen 12 hours postoperatively, graft of good color despite poor response to vasodilatation treatment. Four days afterwards flap turned cold, blue and precarious within 24 hours. Immersions continued and eventually entire graft survived without loss of tissues.



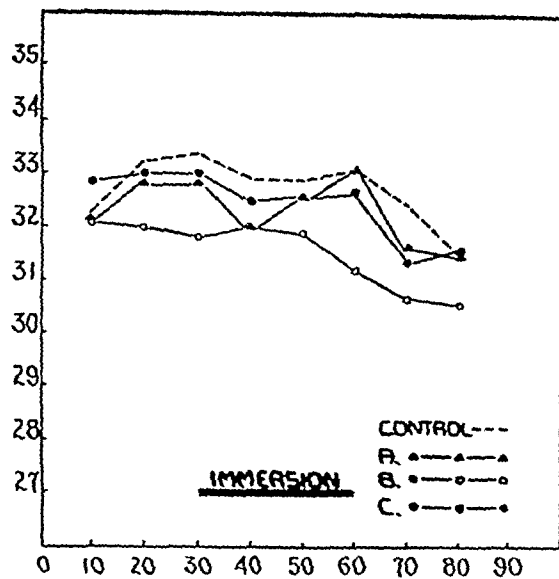
GRAPH 8A

GRAPH 8A.—K. A. H., a 21-year-old male, 8.5-inch abdominal tube formed to restore the defect in the leg, then attached to hand at one end, subsequently abdominal end attached to the thigh. Seen now in this stage (tube from hand to thigh, type-C), Point C was at the hand end of the graft. Despite poor response of central portion of tube, good color was maintained. Studied four weeks postoperatively. Note poor general reaction. Control area—cheek.

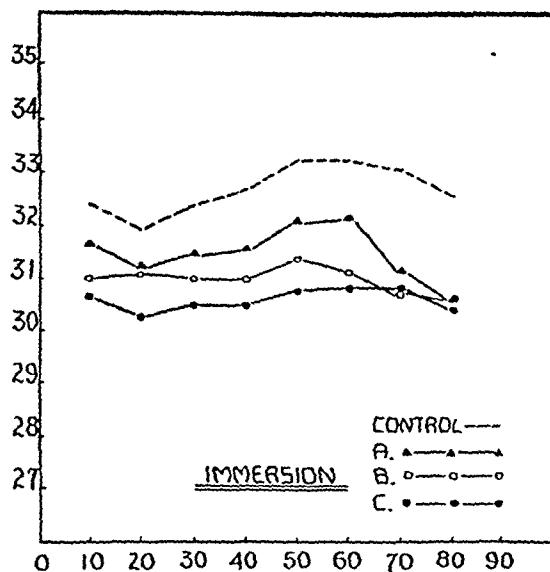


GRAPH 8B

GRAPH 8B.—K. A. H. (same patient as Graph 8). Sixteen hours after the hand attachment severed and replaced in thigh. Color good, with good return of circulation after pressure. Point A was near first attachment to thigh compared with previous poor response. Tube type-C.



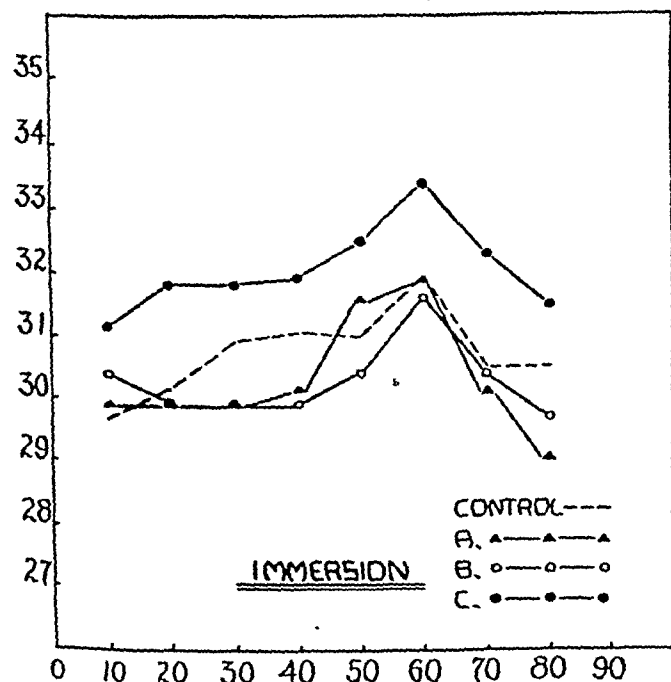
GRAPH 9A



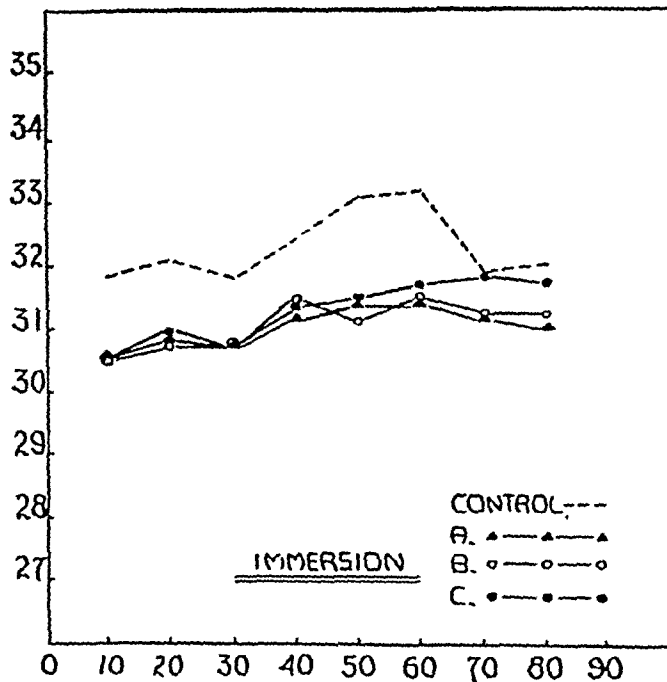
GRAPH 9B

GRAPH 9A.—Major D., a 45-year-old male. Had postradiation necrosis to thyroid cartilage and neck tissues. Ten-inch tube formed on back and slung over right shoulder so that one end of graft attached to anterior surface and the other end *in situ* on back (type-B tube). Case believed inadequately prepared before immersion—felt slightly chilly at end of preparation period. Note that temperature in tube maintained during immersion, but that other surface areas fell conspicuously in second resting period (postimmersion). Control area—cheek. Point A was taken on back near natural site of attachment.

GRAPH 9B.—Major D. (same patient as Graph 9A). Twenty-four hours previously the back attachment of tube severed and slung into position in front of thyroid cartilage and sutured to provide a new anterior surface for the neck. The newly-sutured end became cyanotic and cool at once. Infrared radiation to abdomen added to immersion of foot giving a diffuse flush of the skin of the cheeks and neck, and the tube changed visibly with a pink flush beginning at the vascular end. Circulation obviously improved and more rapid return of color after gentle pressure (tube type-C). Point A—older attached end. Point C—newly attached end tube cyanotic. Control area—abdomen.

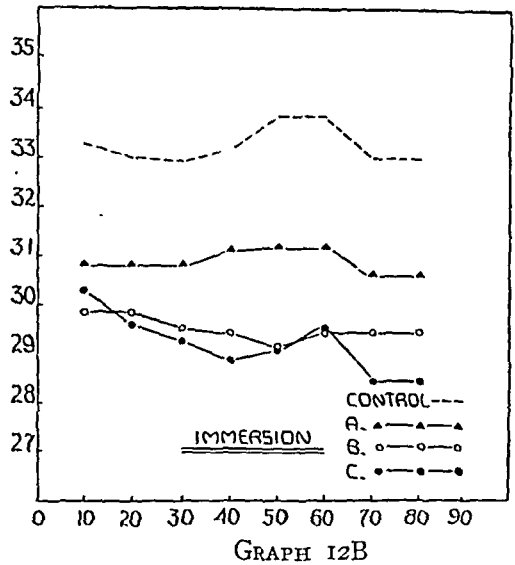
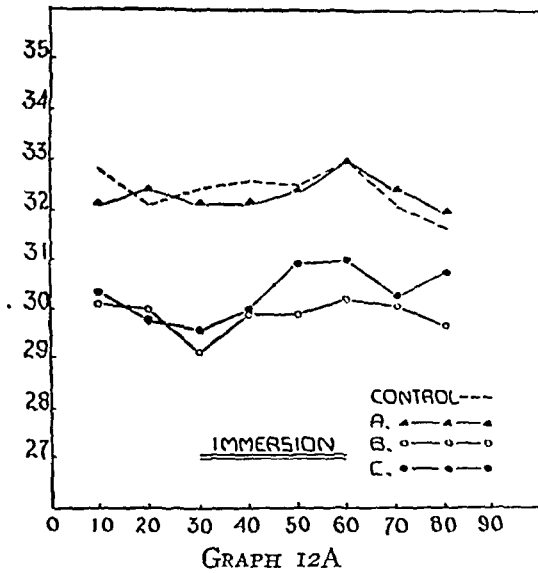


GRAPH 10.—B. G. A., a 26-year-old male with abdominal tube extending from the wrist to thigh (type-C tube), 28 days postoperatively. Good color and return of circulation after gentle pressure. Point C—older attached end. Control area—check. Excellent response to immersion. Notice lag in rise at Point B in center of tube.



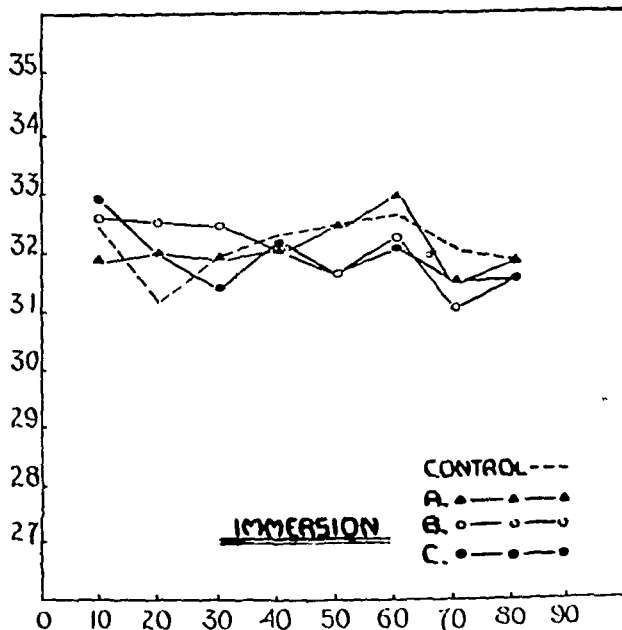
GRAPH 11.—P. P., a 26-year-old male, seen eight days postoperatively, with type-C abdominal tube growing in forearm to reconstruct fleshy defect in upper limb. The abdominal attachment then severed eight days previously and Points A, B and C chosen so that A is at the older attachment, and B and C at more recent attachments, respectively. Control area—cheek.





GRAPH 12A.—W. T., a 22-year-old male, with type-A nine-inch abdominal tube for reconstruction of hand—32 days postoperatively. Color, warmth and appearance excellent. Point C lower end of tube. Control area—cheek.

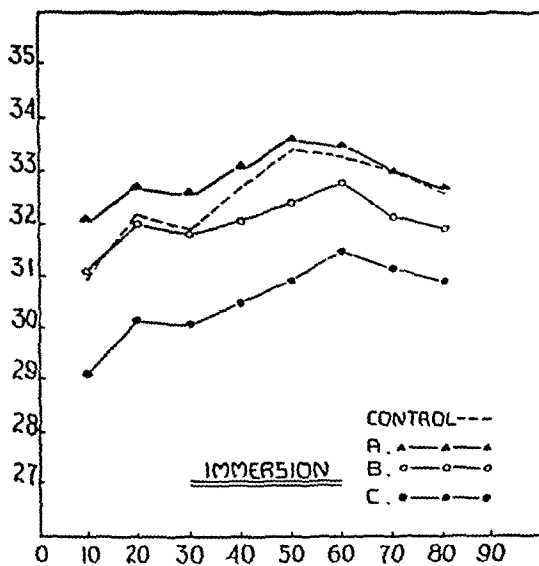
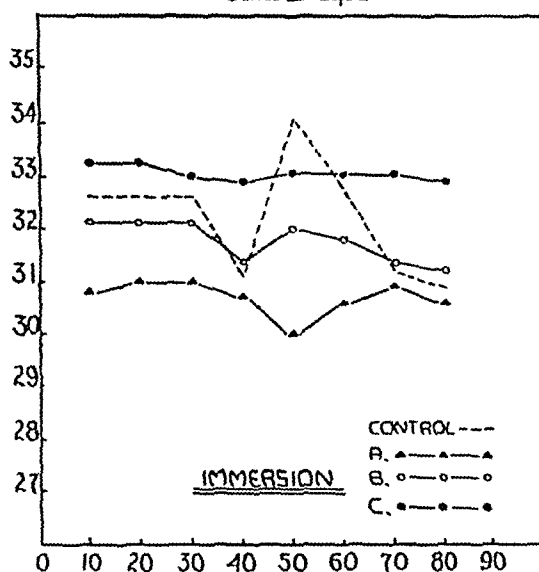
GRAPH 12B.—W. T. (same patient as Graph 12). Seen 12 hours after next stage at which the lower end of tube attached to hand (type-B tube). A attached at the upper end (abdominal tube). Note main vascular supply at abdominal end and rapid fall of Point C directly after immersion period. Control area—neck.



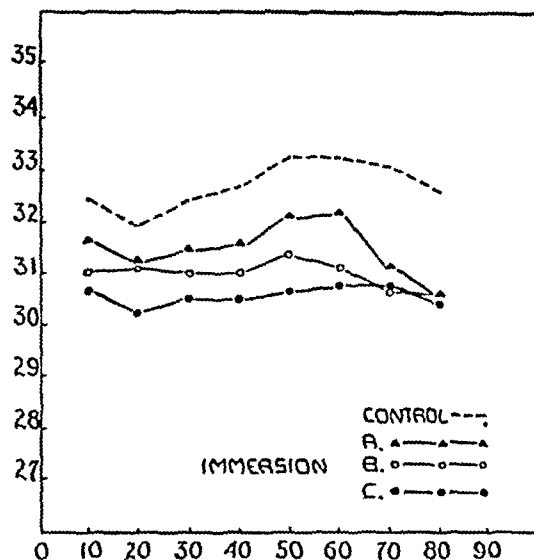
GRAPH 13.—Lieut. T., a 20-year-old male, with 12-inch abdominal tube without intermediate bridge. Type-A. Studied 19 days postoperatively. Region of Point B (center of tube) showed a 1-in. x 1-in. ulcer, with infection, and poor vascular return to gentle pressure. Point A lower end of tube. Control area—cheek.

# VASODILATATION IN TUBED GRAFTS

GRAPH 14A



GRAPH 14B



GRAPH 14C

GRAPH 14A.—R. T., a 22-year-old male, with six-inch abdominal tube for reconstruction of nose. Tube now extending from right wrist to nasal site, 16 days post-operatively. Patient sat up for 15 minutes during immersion period, blanched, and began to perspire and felt dizzy. Temperatures all fell accordingly. Point A near wrist attachment, Point C near nasal attachment. Control area—axilla. Repeated a few days later (see Graph 14B).

GRAPH 14B.—R. T. (same patient as Graph 14) repeated, with patient remaining lying down. Control area—cheek.

GRAPH 14C.—R. T. (same patient as Graphs 14 and 14B) studied 12 hours after arm attachment severed, Point C taken on upper part of new nose, Point A at the lower end of nose (older attachment). Control area—chest.

The common known responses in peripheral circulation as described by Lewis<sup>3</sup>, namely, the white reaction, the red reaction, the flare, and the wheal, illustrate that capillaries can react independently of nerve supply.

Gibbon and Landis<sup>2</sup> propounded two mechanisms to explain why warming one forearm produces vascular dilatation in the opposite hand. First, they state that sensory impulses from the heated limb, by reflex nervous mechanism, produce arteriolar dilatation in the opposite limb. Secondly, quot-

ing Pickering, they state that heated blood flowing centrally acts on a heat controlling center in the hypothalamus and through this reflexly brings about changes in the vasomotor tone. This center responds to phenomenally small variations, a change of 0.1 degree centigrade being sufficient to elicit a response.

Duthie and McKay<sup>4</sup> studied vasomotor reflexes in relationship to body temperature control. They investigated the phenomenon of widespread vasodilatation when heat was applied to one limb and concluded two mechanisms were responsible. One was a peripheral reflex vasodilatation from afferent impulses in the heated limb, the other the effect of heated blood on the thermosensitive center of the hypothalamus. They state: "Vasomotor reflexes from the skin may compensate for moderate variations in environmental temperature by increasing or decreasing heat elimination from the skin. Should these variations become more extreme a rise or fall in internal temperature will follow. The change in blood temperature by its action on the thermocenters in the hypothalamus leads to more vigorous conservation or elimination of heat."

Lewis and Grant<sup>5</sup> observed a flush in denervated digits following release of a pressure cuff which had been causing arterial occlusion. Goldblatt<sup>6</sup> studied hyperemic responses occurring independently of the nervous system. To eliminate sympathetic fibrils reaching the periphery along vessels he sectioned the latter and restored continuity by small glass tubes. He concluded that vasodilatation could occur independently of nervous connections. Doupe<sup>7</sup> concluded that reactive hyperemia is not dependent on any nervous mechanism and, in the denervated digit, is mediated in part by arteriovenous anastomosis.

In opposition to this, Lewis and Pickering<sup>8</sup> state: "While loss of sympathetic supply causes the corresponding fingers to be in general warmer than they otherwise would be, loss of all nerve supply causes the corresponding fingers to be in general colder than they otherwise would be, and, since with combined loss of motor and sympathetic supply the digits remain warm, it seems that the sensory nerve loss must be an important factor in determining the persistent coldness in cases of mixed nerve lesion."

It seems then that agreement has not been reached as to which of the various possible mechanisms produces vasodilatation in limbs remote from a source of heat. One thing appears certain, capillaries are capable of constriction or dilatation, on adequate stimulation, without involvement of any nervous mechanism. Landis<sup>9</sup> points out that local heat dilates capillaries. Thus, endothelial cells, although devoid of smooth muscle, can react to suitable stimulation by contraction or relaxation.

Arteriolar dilatation, in tissue still under nervous control, is the result of a much more powerful mechanism. However, one thing must be emphasized in discussing so-called denervated tissue—it is a serious error to describe an insensitive area as denervated when one tube attachment still remains. So far as the writers know the relationship between cutaneous nerve supply and autonomic supply still present has not been thoroughly studied. Do sympa-

thetic fibrils mediated by vessels supply the same territory as cutaneous nerves in the attachment, or have they wider ramifications?

Doupe and Cullen<sup>10</sup> report two cases indicating that, in denervated tissue as in normally innervated tissue, hyperemia follows injury.

We may conclude, therefore, that where nervous connections exist, strong vasodilator responses are possible but, on their absence, other mechanisms can account for some degree of vasodilatation. It would appear that capillaries and peripheral vessels can dilate or contract in direct response to minute temperature changes of blood. It is certain that denervated tissue responds rapidly to cold stimuli. Doupe<sup>7</sup> states: "The tendency to coldness of completely denervated digits is due to the hypersensitivity of the local vasoconstricting action to cold caused by the degeneration of the sympathetic fibers."

### RESULTS

Before attempting to evaluate the results of this investigation certain points should be made:

(1) Temperature changes of less than 0.5 degree centigrade are not considered significant.

(2) Temperature maintenance during immersion, with subsequent fall in the later resting phase is as significant as an elevation.

(3) All tubes were protected from the underlying skin by dressing pads; thus, except for the attached ends, eliminating conducted heat.

*Type-A Tube Grafts.* The lower end of cervical tubes, fashioned for the repair of the helix of the ear, obviously carried the better blood supply; and, retaining diminished sensation, alone showed vasodilator response. The main response and higher temperature is at the lower end in abdominal tubes also. It would appear that, if an abdominal tube has to be lengthened at a second operation it should be done from the upper end.

Despite the fact that abdominal skin responds to a lesser extent to reflex dilatation than the skin of the neck or cheek the temperature in a type-A abdominal tube can be definitely raised, and presumably vascular channels dilated, by immersion of one limb in hot water. (See Graphs 3, 4, 5, 12 and 13.)

*Type-B Tube Grafts.*—Graphs 5a and b, 7, 9, 12a and b: It is hard to understand why there should be as good a response to vasodilatation over a newly attached end as over a natural attachment. It is believed that trauma liberates H-substance, shown by Lewis<sup>3</sup> to dilate arterioles. Possibly the absorption of this substance explains the hyperemia, and the rise in temperature is due to heat by conduction from inflammation.

Case 12(a) did not show any reaction to immersion; no appreciable response on any control site, and no response on the tube.

*Type-C Tube Grafts.*—Graphs 8a and b, 9a and b, 11, 14a and b: These denervated tissues showed less response in their central portions than in other types, and the older attached end invariably showed a greater rise in temperature than the newer attachment. Some of these type-C tubes showed a rise

of 1.7 to 2.0 degrees centigrade. This increase in surface temperature proves a material increase in blood supply.

The response of these grafts to cold is marked. The sudden drop after the immersed limb is removed from the heat bath may be due to the cessation of heat supply, a reaction similar in nature to the cold sensitivity described by Doupe<sup>12</sup>. These falls in temperature are present in almost every experiment.

One case<sup>6</sup>, subsequent to implantation of his tube into the thigh made good progress for two weeks. His type-C tube was of good color, warm, and appeared healthy. One night this insensitive tube was exposed, by error, to a cool breeze from an open window for some time. When noticed, it had turned cold and cyanotic. Massage and immersion saved it although its color remained dark for several days. We believe that this was just such a reaction to cold as described by Doupe<sup>7</sup>.

#### SUMMARY

Reflex dilatation as a means of increasing blood supply to tubed pedicle skin grafts has been studied in 14 patients. Appreciable rises in temperature were obtained in all but two cases when a limb was immersed in hot water.

Vasodilatation is not dependent on an intact nerve supply, although greater responses are seen when nerve supply is present.

Tubes show a marked sensitivity to the withdrawal of heat, a point to be borne in mind in the after-care of tubed pedicle skin grafts with precarious circulation.

It would appear that abdominal tubes are better lengthened from the upper end.

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# RHABDOMYOSARCOMA OF THE SKELETAL MUSCLES

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IN 1854, over 90 years ago, Weber described a localized enlargement of the tongue of a 21-year-old man. This was excised but later reappeared. It was made up of striated muscle cells in all stages of differentiation from adult to embryonal forms. Although this is not called a neoplasm by Weber there can be little doubt that it was a rhabdomyosarcoma. During the intervening years there have been published many studies of striated muscle tumors. One can learn from them that these are tumors of very variable gross characteristics, rate of growth and appearance, that they affect both sexes, all ages from the newborn infant to the octogenarian, that they grow at enormously variable rates of speed and develop in animals as well as man [rats and mice (Haagen-sen and Krehbiel; Morpurgo; Nettleship); fish (Kolmer); birds (Peyron); cow (Prochazka)]. They have been found in certain definite systems and regions of the body. These are more particularly the genito-urinary system (bladder, kidney, prostate, testis, spermatic cord, uterus, vagina, round ligament and ovary), the heart, upper respiratory and alimentary tracts, the orbit, and sporadic examples have been found in the lung, breast, esophagus, suprarenal and brain. In addition, the writer has been able to locate reports of 107 cases which have developed in the striated muscles and other soft parts of the body. From the clinical point of view this is the more interesting group because many of them develop in situations where they can be subjected to attempts at curative therapy. Therefore, it is of very considerable importance to learn the biologic characteristics as well as the gross and microscopic features of these tumors so that they may be recognized as early as possible and the best form of treatment employed. When the writer undertook to learn what he could from published work, he found that there have appeared a number of magnificently illustrated studies of the neoplastic myoblast by Glasunow, Montpellier, Peyron, Roskin, Temofeevskiy and Wolbach which make it relatively easy for those who use good technical practices to recognize the growth microscopically provided the tumor demonstrates some evidence of differentiation. But when one tries to find out about the biologic habit of the tumor and especially about the efficacy of treatment, the astonishing fact emerges that apparently no statistical investigation has been published—at least in the more easily accessible journals. Bick, Burke, Landois and Lenormant have each produced studies of tumors arising in voluntary muscles but without any attempt to distinguish between the various histologic types. Geschickter, Gordon Taylor, Moulonguet and Pollosson, and Rakov have studied groups of rhabdomyosarcomas but without furnishing enough details to enable one to make much use of them for statistical purposes. Shanin's paper

is in Russian, and the English abstract lacks essential details. De and Tribendi give valuable details of 13 cases and Jönsson has produced a splendid monograph in English from the material of the Radiumhemmet, in Stockholm, with the necessary clinical data of 39 cases of rhabdomyosarcoma of the peripheral voluntary muscles, each one of which was diagnosed by Reuterwall. All of the writers mentioned have realized the extremely malignant nature of the rhabdomyosarcoma but not even Jönsson, who had the information at his disposal, studied it statistically and made use of it to emphasize his conclusions.

The writer has, therefore, tabulated the published cases and added 14 unpublished ones at his disposal, making a total of 121 cases for analysis. Before this analysis is presented, it seems necessary to discuss the histology, classification and nomenclature of these tumors so that it may be perfectly clear what is meant by the name used and what tumors are included.

In this paper the intention has been to present the tumors that are definitely made up of cells which, in whole or in part, have some of the characteristics of rhabdomyoblasts and which have arisen in the striated muscles (exclusive of heart muscle) or immediately adjacent to them. The rhabdomyoblastic tumor cell is very variable in size but in general it is rather large and it assumes one of three different shapes. It is either rounded, strap-shaped with two or more nuclei arranged in tandem, or racquet-shaped with a single nucleus at one expanded, rounded end, and a tapering body extending outward from this for a variable distance. The cytoplasm is generally somewhat acidophilic, and sometimes markedly so. It is often granular. If the tumor material is well-fixed and stained with either Masson's trichrome stain containing acid fuchsin, Haidenhain's hematoxylin or (if Zenker fixation is used) with the phosphotungstic acid-hematoxylin stain, either cross-striations, longitudinal myofibrils or some vague suggestion of their formation should be distinguishable in the majority of cases. It is usually not easy to find this differentiation even with very good preparations and one must be willing to make a painstaking search with high magnification. But the search is rewarding if successful, for the diagnosis can then be made with complete assurance. One or the other of these differentiating features was found in nine of the 14 new cases here recorded. In embryonic myoblasts or myoblasts from adult striated muscle *in vitro* (Pogogeff and Murray), the formation of cross-striations and longitudinal myofibrils is markedly variable; they appear, disappear and reappear within a cell sometimes rapidly and sometimes after long intervals. Moreover, the cross-striations often do not completely traverse the elongated strap-like cells. Reproduction of these vagaries is found in tumor myoblasts (Figs. 5, 7, 10 and 11). The tumor cells are sometimes vacuolated and it has been generally accepted that the material in the vacuoles is glycogen, since Marchand demonstrated this in 1885. Glycogen determinations have not been done in any of the new cases reported here. When there are many vacuoles in cells of giant size, they are sometimes peripherally arranged with delicate cytoplasmic strands separating them and radiating outward from near the nucleus to the capsule. Such cells have been called spider or spider-web

cells. But even if one is unable to demonstrate cross-striations and fibers the other histologic features will usually suffice to make the diagnosis. Jönsson reported that he did not find them in a single one of his 39 cases of rhabdomyosarcoma. The photomicrographs, however, are sufficient to enable one to accept his cases as authentic, especially when one is assured that they were all studied by Olle Reuterwall. It should be noted that the rhabdomyosarcomas may not show these characteristics in all parts. One may encounter fibrous areas, as in Case 14 of this series, which show no characteristic features (Fig. 13). Such a vagary may be found in many tumors of specific cell origin and in the opinion of the writer simply represents the ability of such cells to assume the guise and function of fibroblasts.

The question arises as to whether or not any of the striated muscle cell tumors of skeletal muscle can be considered benign like those which develop in the heart muscle. The latter are highly specialized relatively well-differentiated growths which are considered congenital malformations by many since they are frequently associated with tuberous sclerosis and kidney tumors and cysts. In the other muscles, however, while a relatively high degree of differentiation, as in Case 9 (Fig. 5), may indicate slow growth, it is no guaranty that it may not infiltrate so that complete removal will be difficult as in Case 11 (Fig. 9). Therefore, while it can be surmised that a tendency to differentiate may be a favorable sign all of these peripheral tumors are malignant to some degree and should, therefore, be classified as rhabdomyosarcomas.

It is impossible to avoid reference in this connection to three other varieties of muscle tumors. Abrikossoff's myoblastic myoma, otherwise known as the granular cell myoblastoma, has been very generally accepted as a tumor of immature myoblasts. Howe and Warren, using the name myoblastoma for them, have indicated that they should be segregated as a group separate from the rhabdomyosarcomas. The writer is willing to agree with this for the present, at least, for the exact nature of these tumors is not yet settled. Tissue culture studies by M. R. Murray in this laboratory have so far failed to prove beyond peradventure the myoblastic nature of these cells. The writer is not in entire agreement with all Howe and Warren have to say about malignant granular cell myoblastomas, for he believes they have included with them some rhabdomyosarcomas; an action which in his opinion serves to confuse rather than to clarify (Ravich, Stout and Ravich).

In addition to the granular cell tumors there have been described some tumors which seem to partake of the characteristics of both smooth and striated muscle cells and others in which it seems impossible to decide whether they are smooth or striated muscle cell tumors. This question has been extensively debated by Roskin, Montpellier, and others. The most confusing pictures are furnished by some uterine tumors in which both smooth and striated muscle cells are found (Lochrane). The writer has not encountered such cases arising in the skeletal muscles and he doubts if there can be many in which such equivocal conditions exist. He is inclined to simplify his nomenclature of the muscle tumors to the following terms: Smooth muscle



cell tumors—leiomyoma, leiomyosarcoma; striated muscle cell tumors—granular cell myoblastoma (benign and malignant types); rhabdomyoma of the heart muscle; rhabdomyosarcoma; undifferentiated myosarcoma (this term to be used only when it is impossible to place the tumor in any of the other groups). Most of the granular cell tumors and the heart rhabdomyomas are benign, while all of the other striated muscle cell tumors are either definitely or potentially malignant. The tumors, for instance, which arise in the genito-urinary system of infants and very young children rarely metastasize but they demonstrate stubborn infiltrative growth, and even most radical surgical procedures have failed to eradicate them.

The tumors with which the rhabdomyosarcoma is most easily confused are liposarcomas and fibrosarcomas. The liposarcomas commonly form bizarre giant cells but the nuclei are very apt to be pyknotic and lipid droplets are always demonstrable in some part of the growth. It is sometimes mistaken for a fibrosarcoma because the cells are often elongated and connective tissue fibers are usually present between them. But the presence of bizarre giant cells in the writer's opinion definitely removes the growth from the fibrosarcoma class and means that it is in fact derived from some other specialized cell such as the lipoblast, osteoblast, rhabdomyoblast, Schwann cell, *etc.* The differential diagnosis of peripheral soft part tumors is always a challenge to the diagnostic acumen of the pathologist.

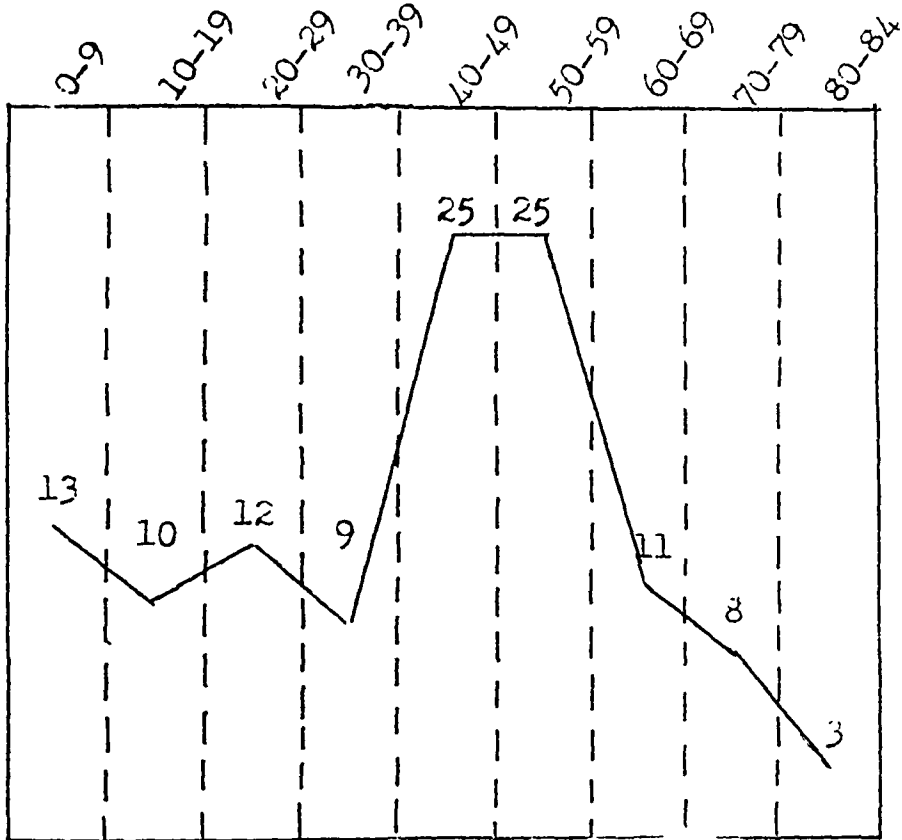
*Etiologic Factors.*—There is a very slight preponderance of males. Among 114 patients whose sex is recorded, there were 62 males and 52 females. The age variation is extreme, as Graph I shows, with the preponderance in the fifth and sixth decades. The mean age was 42.1 years at the time of diagnosis. Of the 116 cases whose age is known, 46 were below the mean. There are no facts suggesting immunity or higher susceptibility in any race or geographic area. Trauma of some degree is mentioned in the histories of 14 tumors or 11.5 per cent (Table Cases 1, 11, 16, 19, 32, 43, 55, 70, 87, 88, 90, 110, 111, 120). This would hardly seem a figure of significance.

*Site of Origin.*—In almost every case the tumor developed either within or attached to a peripheral striated muscle. Since Case 78 had two apparently independent tumors in the thigh and axilla and Case 100 tumors in both arms, the distribution of 123 tumors from the 121 cases will be recorded. Lower extremity: 52 cases (thigh 33, leg 18, foot 1); upper extremity: 17 cases (arm 9, forearm 7, and hand 1); trunk: 31 cases (back 11, chest 8, buttock 6, groin 4, abdominal wall 2); head and neck: 19 cases (tongue 10, neck 6, head 3); diaphragm: 3 cases; psoas muscle 1. As is the case with other malignant tumors of the soft parts and bones, the thigh and leg are the favored sites of origin.

*Duration of Disease.*—In 48 cases the total duration of disease is known from the onset of symptoms until death. The mean is 30.25 months, with the extremes of two months (Case 90) and 162 months (Case 20). If two extremely long survival cases are omitted (Cases 20 and 93), the mean for the remaining 46 is only 24.9 months. There are, however, several other cases of very long duration of the tumor in which the total duration is not

known. Since they are referred to later in this paper attention will be directed only at this point to Case 38, with a reputed duration of 50 years. It is evident that one must be very cautious in predicting the probable duration of one of these tumors.

GRAPH I  
Age Distribution of 116 Cases of Rhabdomyosarcoma of  
Muscles and Soft Parts



Mean Age—42.1 years. Variation 0-84

*Symptoms.*—Commonly the only symptom is tumor which in 88.5 per cent developed without any history of antecedent trauma and often without pain or interference with function. Increase in size is sometimes rapid and sometimes extremely slow and a considerable bulk may be attained although not as a rule the massive proportions of many liposarcomas. The deep situation and muscular involvement produce a moderately firm deep-seated mass, which is of very limited mobility. Sometimes growth of the tumor compromises the overlying skin and the tumor fungates. This may also happen after biopsy. The appearance is shown in Figures 3 and 12.

*Gross Characteristics.*—The tumor tissue varies greatly in its hardness because of the great variation in the amount of collagen in it. Generally it is rather soft, somewhat reddish and may be mottled with various tints of red and cream from hemorrhage and necrosis. It is often circumscribed but always infiltrates surrounding tissues, although it is not always possible grossly to demonstrate this.

TABLE I  
RHABDOMYOSARCOMA  
REPORTED AND PERSONAL CASES

Author	No.	Sex	Age	Site	Dur.* A.T.	Excision													Pre- op. Rad.	Post- op. Rad.	Re- cur.	Met- as.	Dead	Alive Tumor	Alive 5 T.	Total Dur. Mos.
						1	2	3	4	5	6	7	13	Amputa- tion	Other Op.	Op.										
Amunategui	1	F	5	Glut. max.		+												+	+					6		
Ardoin	2		3	Temp. mast.		+												+	+	+(6)						
Benison (Case 7)	3	F	23	Coraco-brach.	7										+							+(0)				
Bérard	4	M	2	Back		+																				
Billroth	5	F	Ad.	Arm	6	+	+	+	+									+	+	+(18)						
Bolanos	6	F	12	Tongue	12	+															+(0)					
Buhl	7	F	28	Sacral		+												+	+		+(0)					
(1)	8	M	50	Chest		+															+(0)					
(2)	9	F	19	Thigh, muscle														+	+					Few		
Cappell (6)	10	M	60	Tongue		+	+	+	+									+	+							
Charache	11	M	44	Thigh	6	+												+	+					48		
Danciger & Warren	12	M	2	Gastroc.														+	+					12		
De & Tribendi	13	F	46	Thigh		+	+											+	+					18		
(1)	14	M	13	Axilla	12	+																		43		
(2)	15	M	38	Hand	60	+																		84		
(3)	16	F	20	Back	11	+	+	+	+											+(24)						
(4)	17	M	39	Thigh muscles	3	+															+(96)					
(5)	18	M	50	Arm																	+(3)			24		
(9)	19	M	48	Thigh	144															+						
(11)	20	M	45	Tongue	108	+	+	+	+															162		
(12)	21	M	11	Leg	36																					
(13)	22	M	½	Tongue	6	+																				
De Castro-Freire	23	M	80	Thigh	3	+	+																			
Desmarest & Masson	24	M	75	Neck																						
Engelbreth-Holm	25	M	62	Thigh	3																					
Fitzwilliams	26	F	40	Neck	132	+	+																	24		
Frank, <i>et al.</i>	27	M	50	Leg	120																					
Fuginani	28	M	32	Leg																						
Genevet	29	F	50	Thigh																						
(1)	30	F	22	Leg																						
(2)																										
(3)																										
																						</				

## RHABDOMYOSARCOMA OF MUSCLES

TABLE I—Continued  
RHABDOMYOSARCOMA  
REPORTED AND PERSONAL CASES

Author Geschickter	No.	Sex	Age	Site	Dur* A.T.	Excision							Pre- op. Rad.	Post- op. Rad.	Rad. Alone	Re- cur.	Met- as.	Dead	Alive Tumor	Alive 5 T.	Total Dnr. Mos.
						1	2	3	4	5	6	7	13	14	15	16	17	18	19	20	21
(2)	31	M	63	Forearm		+															
(3)	32	M	17	Leg	2	+															
(4)	33	F	44	Sacral		+	+							+							
Glasunow																					
(3)	34	M	74	Thigh	12	+	+														
(4)	35	M	32	Leg	7									+							
(5)	36	F	18	Thigh	24																
Halley	37	M	40	Calf	60	+															
Harper & Feder	38	M	75	Neck	600	+	+														
Johan	39	F	44	Arm	5	+	+														
Jönsson																					
(1)	40	F	65	Back	6	+	+	+													
(2)	41	F	55	Thigh	2	+	+														
(3)	42	M	78	Groin																	
(4)	43	F	45	Gluteal																	
(5)	44	M	47	Leg		+	+														
(6)	45	F	44	Chest		+	+														
(7)	46	M	57	Arm	24	+	+	+	+	+	+	+									
(8)	47	M	55	Thigh		+	+														
(9)	48	F	48	Thigh	6	+	+														
(10)	49	M	57	Thigh	1																
(11)	50	F	36	Thigh	24																
(12)	51	F	61	Leg	3	+															
(13)	52	M	57	Thigh, gluteal	10																
(14)	53	M	56	Leg	1	+															
(15)	54	M	80	Leg	1½																
(16)	55	M	48	Knee	8																
(17)	56	F	28	Chest	2	+															
(18)	57	F	59	Leg	7																
(19)	58	F	52	Abd. wall	1½																
(20)	59	F	57	Thigh	3	+	+														
(21)	60	F	48	Thigh	3																

TABLE I—Continued  
RHABDOMYOSARCOMA  
REPORTED AND PERSONAL CASES

Author	No.	Sex	Age	Site	Dur.* A.T.	Excision													Other Op.	Pre- op. Rad.	Post- op. Rad.	Rad. Alone	Re- cur.	Met- as.	Dead	Alive Tumor	Alive - T.	Total Dur. Mos.	
						1	2	3	4	5	6	7	13	Ampu- tation															
(22)	61	F	63	Groin	6																								9
(23)	62	F	45	Thigh	24	+																							42
(24)	63	F	57	Gluteal	3	+																							29
(25)	64	F	16	Thigh		+	+																						
(26)	65	M	78	Back	1	+	+	+																					
(27)	66	M	77	Groin	18	+																							
(28)	67	F	52	Thigh	1	+	+																						79
(29)	68	F	41	Abd. wall	4	+																							
(30)	69	M	69	Gluteal	3	+																							
(31)	70	F	28	Thigh	10	+																							15
(32)	71	M	48	Forearm	18	+	+																						
(33)	72	M	30	Thigh	5½	+																							28
(34)	73	F	47	Back	1	+																							17½
(35)	74	M	46	Thigh	18	+																							
(37)	76	F	52	Leg	6																								
(38)	77	F	53	Thigh	4	+	+																						
(39)	78	F	58	Thigh and axilla	44	+																							
Kirschbaum (1)	79	M	47	Diaphragm	36																								
Lepage	80	M		Submax.		+	+																						3½
Ligas	81	M	53	Thigh	5	+																							
Lino	82	F	24	Tongue		+																							
MacCallum (1)	83	M	59	Arm	1	+	+	+	+																				
(2)	84	F	70	Leg	12	+																							5½
Marchand	85		4	Gluteal																									
Von Meyenburg	86	M	57	Tongue		+																							58
Muller	87	M	48	Thigh			+																						13+
Ono	88	M	24	Forearm	1	+	+																						
Oswald	89	M	36	Neck	36±	+																							
Peery & Smith	90	M	14	Diaphragm	2																								
Pendi	91	M	0	Tongue	2	+																							2
Rakov (7)	92	F	47	Arm		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	

RHABDOMYOSARCOMA OF MUSCLES

TABLE I—Continued  
RHABDOMYOSARCOMA  
REPORTED AND PERSONAL CASES

Author (12)	No. 93	Sex F	Age 48	Site Arm	Dur* A.T.	Excision							Other Op.	Pre- op. Rad.	Post- op. Rad.	Rad. Alone	Re- cur.	Met- as.	Dead + (12)	Alive Tumor	Alive s T.	Total Dur. Mos. 144
						1	2	3	4	5	6	7	13									
Ribbert (1) (2)	94	M	boy	Temporal	+	+																
	95	M	boy	Face	+	+													+	+(0)		
Richmond (1) (2)	96	M	45	Thigh	36	+																44½
	97	F	59	Thigh	9	+																
Rytz (1) (2)	98	M	0	Tongue	5	+																
	99	F	51	Diaphragm	2	+																
Scott-Carmichael (1) (2)	100	M	56	Arm (bilat.)	3	+																
	101	M	66	Forearm	12	+	+															
Stulz, et al. (1) (2)	102	M	0	Neck	6	+	+															
	103	M	4½	Tongue	12	+	+															
Thomas (1) (2)	104	F	21	Psoas		+																
	105	F	7½	Back		+																
Warnery (1) (2)	106	M	21	Tongue	1½	+																
	107	F	4	Back		+																
Wolbach (1) (2)	108	M	22	Thigh	4																	
	109	M	21	Leg	8																	
(3) (4)	110	M	47	Thigh	7																	
	111	F	19	Leg	1	+																
(5) (6)	112	F	35	Back	5		+															
	113	M	75	Gluteal	6																	
(7) (8)	114	F	63	Forearm	9																	
	115	M	56	Thigh	¼	+																
(9) (10)	116	F	33	Arm	12	+																
	117	M	Forearm	12	+	+																
(11) (12)	118	F	15	Back	5±	+																
	119	M	53	Axilla	½																	
(13) (14)	120	M	69	Chest wall	5	+																
	121	F	66	Foot	32	+																

\* Duration before treatment.  
All duration figures are recorded in months.

*Spread.*—The insidious character of the local invasive spread of the tumor is indicated by the high incidence of local recurrence after treatment, 108 cases received some kind of an attempt at curative treatment. Local recurrence was noted in 66, or 61 per cent. Spread also takes place through the blood and lymphatic systems. Thirty-eight patients are known to have had metastases. The site of these was as follows: Lungs 23, lymph nodes ten, skin and subcutaneous tissues eight, pleura seven, bones five, liver three, kidney, suprarenal mediastinum and pericardium two each; pancreas, ovary and brain, one each. Metastases were generalized in only five cases.

*Duration of Tumor before Treatment.*—This is recorded in 84 cases, and the mean duration for these is 23.2 months. But five cases had an inordinately long duration of from nine to 50 years before treatment was undertaken. If these are omitted, the other 79 cases had a mean duration of 10.7 months, with a variation from a few days to five years.

*Treatment.*—Reference to Table I will show that many different ways of dealing with these tumors have been employed. These have consisted principally of simple excision, amputation and, to a less extent, radiotherapy. Often two or all three methods have been employed. In so far as *radiotherapy* is concerned, it has been used as the sole method of treatment in 12 cases, without any good results. In all the tumor persisted and in ten the patient is known to have died. Preoperative radiation was used in 14 and postoperative radiation in 35 patients. Since operations were also performed, one cannot know whether or not the radiation had any important effect. It seems very questionable that it did. Postoperative radiation was used in Case 40 and failed to prevent a local reappearance of the tumor. When this was removed by electrocoagulation the patient then remained free of tumor for nearly ten years before dying of complications following a fracture. In Cases 66, 73, 74 and 78, the patients were symptom-free for eight, 18, 18 and 12 months after excision and radiotherapy but there is no further information about them and the periods are too short to be significant. Stewart found that the few rhabdomyosarcomas treated by radiotherapy at the Memorial Hospital were resistant. We may conclude that the tumor is certainly little affected by ordinary doses. Whether or not huge doses pushed to the limits of tolerance would accomplish anything more important remains to be determined.

The first treatment of 80 cases was an attempt at local excision of the tumor. Twelve of these were not followed and five more were without evidence of tumor less than five years (at 48, 8, 18, 12 and 4 months). Only two remained well five or more years. Case 56 had a tumor of the chest wall below the clavicle which grew rapidly for two months and was treated by excision with pre- and postoperative radiotherapy. When last seen, 71 months after operation, she was symptom-free. Case 116 had a small tumor excised from within the triceps muscle only one week after the tumor was found. Five years afterwards there was no evidence of recurrence. Of the remaining 63 patients all had recurrence or metastases and 36 had subsequent operations, either further excisions (to the number of 13 in Case 93) or amputation or both. Of these all but three are dead or were last seen with tumor persisting.

Case 26 had a 6 x 5 cm. tumor in the neck deep to the muscles for 11 years. It had eroded the vertebrae and reached the spinal canal, producing pressure symptoms. Excision was incomplete and after one month a second excision was done supplemented by radium in the wound and postoperative roentgenotherapy. Three years later there was no evidence of recurrence. Case 102 was also in the neck and was congenital. It was incompletely removed from its deep situation and a second excision was carried out one month later. Six months after the second operation the child was well. Case 118 is Case 11 reported in this paper. Twenty-five months after removal of the primary tumor from the rhomboideus muscle a recurrence was excised, and 51 months after the second operation she was well. With these should be mentioned Case 40 who died of injuries and was without evidence of persistence nine and two-thirds years after the last of three attempts to remove a tumor of the back.

Primary amputation or amputation after biopsy was carried out 16 times. Seven were not followed, two died as a result of the operation, six had recurrences or metastases and only one had a good result. This is Case 32, which had a primary amputation for a tumor of the leg and was reported well 11 years later.

Of the 13 remaining cases, there was either no treatment or there is none recorded.

There are several cases of long survival with the tumor persisting which should be noted. Tumor persistence of nine years is noted in Cases 16 and 20, ten years (Case 27); 11 years (Case 92); 12 years (Case 19);  $13\frac{2}{3}$  years (Case 20); 14 years (Case 26); and 50 years (Case 38). It is quite evident, therefore, that rhabdomyosarcoma may persist for a very long time without killing.

From the above data it will be appreciated that it is impossible arbitrarily to select the best form of treatment, since of four long survivals without evidence of persisting tumor one (Case 32) was treated by primary amputation alone; one (Case 116) by simple excision alone; one (Case 56) by simple excision with pre- and postoperative radiotherapy; and one (Case 40) by excision and postoperative radiotherapy followed by two subsequent excisions of recurrences. It is manifest, however, that in a very large number of cases the first procedure was an inadequate excision and one should be able to cure this neoplasm more often if it is attacked earlier and in a more radical manner. Long study of cases of malignant tumors of the peripheral soft parts and bones has convinced the writer that they should not be attacked by blind removal before obtaining definite knowledge of their nature by biopsy. If the tumor is treated without knowledge of its nature one runs the hazard of removing too much or too little; usually the latter. A small biopsy removed with the minimum amount of trauma will furnish the information necessary for proper action and of itself will do no harm. In the case of the rhabdomyosarcoma, treatment should certainly be radical with removal of a large block of surrounding uninvolved tissues. This may or may not mean amputation.



## CASE HISTORIES

**Case 1.**—(Table No. 108): M. C., male, Jewish presser, age 22, was first seen at the Presbyterian Hospital, October 14, 1921. He had noted a swelling the size of a hen's egg on the inner aspect of the right thigh for three months, which appeared without history of injury. It was hard, freely movable, and painless until two weeks before admission. It increased rapidly in size so that on admission the circumference of the right thigh was 48 cm. in comparison with 39 cm. for the left. The swelling of the thigh was diffuse and extensive measuring 24 x 14 cm. Wassermann reaction negative. Roentgenograms showed a soft-part tumor without bony involvement. Aspiration yielded only blood. October 21, 1921, a biopsy was taken which was diagnosed as a malignant sarcoma. The wound did not heal well because the tumor grew up into it. The patient refused amputation. A small amount of low voltage roentgenotherapy was given to the thigh and to the chest after roentgenograms of the lungs, November 2, 1921, showed shadows suggestive of pulmonary metastases. A secondary metastatic mass appeared on the anterior surface of the right leg. Because of pain and ulceration the patient consented to disarticulation of the right hip November 15, 1921. The pulmonary metastases enlarged rapidly, and he died January 9, 1922.

*Grossly* (S. P. 26812) the tumor was 32 cm. in length with a maximum thickness of 8 cm. where it ulcerated through the skin. It was soft orange-pink with areas of hemorrhage. It involved the vastus medialis muscle but not the bone. In the leg anteriorly were two secondary subcutaneous nodules of similar appearance.

*Microscopic:* Very large strap cells with hyperchromatic nuclei often in tandem arrangement. Occasional rounded giant forms. Much blood pigment. No longitudinal or cross-striations and no vacuolated spider cells seen. Cytoplasm moderately acidophilic. (No special stains available.)

**Case 2.**—(Table No. 109): R. L., white American farmer, age 21, was admitted to the Presbyterian Hospital, July 16, 1932. He had noticed, by chance, a painless, egg-sized swelling of the lateral side of the right calf at the midpoint of the leg eight months before. Five months before it began to be painful after he had been walking. Fifteen days before a biopsy was taken elsewhere and called a mixed cell sarcoma. Examination showed a 6 x 8 x 12 cm. mass in the outer part of the right gastrocnemius muscle. Roentgenotherapy was begun July 18, 1932, and carried on sporadically until October 15, 1932. Large fields were used (15 x 20, 20 x 20, and 15 x 15 cm.), 180 to 200 KV; 50 cm. A. S. D. and filtration 0.55 Cu. plus 1, mm. Al. A total of about 8,520 r was given through the various fields to the leg. Toward the end of this period two nodules appeared in the popliteal space which were biopsied November 17, 1932, and proved to be metastases. The extremity was amputated through the midthigh November 23, 1932. Following this he had a great deal of pain in the right groin and right lower quadrant with enlarged tender inguinal nodes. Roentgenograms of spine and chest showed no evidence of metastases. Cordotomy for relief of pain was contemplated, but before this could be arranged the level of the pain had ascended so high that this was abandoned. He died at home, February 11, 1933.

*Gross* (S. P. 49920) (Fig. 1): The tumor measured 7 x 8.5 cm., it lay within the gastrocnemius and soleus muscles. The cut-surface was grayish mottled with red areas of hemorrhage and yellow areas of necrosis. There were four other separate nodules in these muscles and others in the tibialis anticus and the popliteal space.

*Microscopic:* The tumor is much altered by the radiation which has produced widespread degeneration, necrosis and fibrosis. Where the cells have escaped they appear as large strap forms with nuclei in tandem, acidophilic cytoplasm and occasionally well-defined longitudinal intracellular fibers. No cross-striations discovered. Many cells are vacuolated. Rare giant cells but no spider forms.

**Case 3.**—(Table No. 110): R. P., a colored dining-car waiter, age 47, first came to the Presbyterian Hospital April 12, 1934. Four years before he hurt his left thigh by stepping into a coal pit, resulting in pain in the medial thigh muscles. Ten months

## RHABDOMYOSARCOMA OF MUSCLES

before he struck the same thigh against a dining-car table. Pain began seven months before, and swelling was first noticed one month later. Gradual increase of symptoms causing some limp. Examination showed a 15 x 20 cm. hard mass in the middle of the left thigh apparently in the vastus medialis muscle (Fig. 2). Not tender and only slightly movable. Wassermann reaction and roentgenograms of thigh and chest negative.



FIG. 1.—Case 2 (Table No. 109) : Rhabdomyosarcoma of gastrocnemius muscle showing secondary nodules.

He was admitted and a biopsy done April 26, 1934. This showed a pale elastic tumor mass deep to the vastus medialis which exuded serous fluid when the biopsy cut was made. The inguinal and femoral nodes were not enlarged. He was treated by a large radium pack with 43 tubes containing from 5 to 12.5 mg. radium totalling 350 mg. The pack was left on for seven days and a dose equivalent to 50,000 r given. This was done May 5, 1934 to May 11, 1934. It was supplemented by 2300 r of high voltage high filtration roentgenotherapy given through anterior and two lateral ports sporadically from April 30, 1934, to October 1, 1934. The mass decreased in size somewhat but never disappeared.

Evidence of spread or metastasis was never obtained but the pain returned, grew much worse, and he died at home February 21, 1935.

*Microscopic.*—(S. P. 54161): Rather large irregularly-shaped cells with finely granular acidophilic cytoplasm. No longitudinal or cross-striations. Some strap forms with nuclei in tandem arrangement. No giant cells but some cells with vacuoles.

**Case 4.**—(Table No. 111): M. L., a white American secretary, 19 years old, Eighteen months before coming to the hospital she bruised her right knee but was able to continue work. Four months later she noticed a swelling over the right shin at the site of a spot which she often used to push in the lower drawer of a filing cabinet. It was the size of a quarter and not discolored. A physician excised it in his office one month later. It recurred in two months and was again locally excised. This wound never healed, and after three months it was excised for the third time four months before

admission. This wound also failed to heal, and when admitted there was a multinodular fungating growth elevated 2 cm. above the surface and measuring 11 cm. vertically and 7 cm. transversely (Fig. 3). Roentgenograms showed no lung metastases. December 9, 1937, a supracondylar amputation was done through the lower third of the thigh. She remained well until March 1, 1939, when evidences of lung metastases appeared. Roentgenograms, July 15, 1939, showed a large mass in the left upper lobe. Two months later this had doubled in size but the girl felt relatively well and remained active until September, 1940. A large recurrent tumor mass then appeared above the amputation site and metastatic nodules in the mammary and clavicular regions. She died at home, November 16, 1940, 35 months after amputation.

*Gross* (S. P. 65768) (Fig. 3): The tumor involved the tibialis anticus, extensor longus digitorum and peroneus longus muscles. It was pinkish in color with hemorrhagic areas, and had a maximum thickness of 4 cm. Two popliteal lymph nodes showed no tumor.

FIG. 2.—Case 3 (Table No. 110): Rhabdomyosarcoma of vastus medialis muscle.

*Microscopic* (Fig. 4): The tumor is composed of bundles of large spindle and strap cells with moderately acidophilic cytoplasm, sometimes granular and sometimes showing longitudinal striations. Cross-striations are demonstrated with difficulty because they rarely traverse the cell completely. Giant cells are occasionally present, some of which are vacuolated.

**Case 5.**—(Table No. 112): L. W., a Jewish woman, age 35, was admitted to the Urologic Department of the Presbyterian Hospital, complaining of five months back pain more severe on the right side. It grew constantly worse, with loss of 15 pounds weight. Examination showed an elastic nonfluctuant mass to the right of D 10 and D 11. It was rigidly attached to the ribs. Roentgenograms showed erosion of the eleventh rib posteriorly. She was transferred to the Fracture Service, and explored December 28, 1937. The tumor was grayish-white with dark hemorrhagic areas. The muscles were infiltrated and the ribs surrounded with tumor penetrating inside the thoracic cage. It

extended transversely from just to the right of the midline to the posterior axillary line. Biopsy was taken and roentgenotherapy started January 3, 1938, and continued to February 3, 1938. The factors were: 200 KV, 25 MA, TSD 50-80 filters varied from 0.5 to 2 mm. Cu. The fields were direct posterior and right and left tangential varying from 10 x 20 to 15 x 15 cm. Twenty-seven daily treatments totaling 400 r direct and 3,000 r to each of the two tangential fields. The treatment had little effect and the



FIG. 3.—Case 4 (Table No. 111) : Rhabdomyosarcoma of leg muscles.

last note stated that eight months after operation she had gone down hill rapidly and would probably soon be dead.

*Microscopic* (S. P. 65925) (Fig. 5) : There are bizarre and strap cells with many longitudinal fibers best shown with Heidenhain's hematoxylin and phosphotungstic acid. Acidophilic intracellular granules sometimes suggest an abortive attempt to form cross striations. There are a few giant cells but no spider forms. There is a well developed connective tissue framework.

**Case 6.**—(Table No. 113) : W. S., white, male, age 75. Six months before admission, without known cause, an area of soreness developed below the flexion crease between the right thigh and buttock. One month before a mass was noted. It lay just caudad to the right ischial tuberosity, measured about 8 x 6 cm., and was apparently deep to the fascia. Roentgenograms of chest and skeleton were negative. Aspiration was done November 14, 1938, yielding soft, gray bloody tissue. Roentgenotherapy was started November 12, 1938, and estimation of the size of the mass at this time was 12 x 14

cm. The factors were: 200 KV, 25 MA, 50 TSD, filter 1 mm. Cu plus 1 mm. Al. The fields were superior delivered in the kneeling position through the buttock receiving 3,000 r, and two lateral fields each of which received 2,000 r. Treatments continued daily from November 12, 1938, to December 22, 1938. Evidence of pulmonary metastases developed April 24, 1939, and he died July 4, 1939.

*Microscopic* (S. P. 68906): The few tumor cells present in the small biopsy are for the most part irregularly rounded and very variable in size with occasional multinucleated giant cells. Some of these have marginal vacuolation of the cytoplasm producing the so-called "spider" effect. No longitudinal or cross-striations are recognized. The cytoplasm is slightly acidophilic and without granules.

**Case 7.**—(Table No. 114): D. F., an Austrian Jewish widow, age 63. Fourteen years before this woman had had a right radical mastectomy for carcinoma, without axillary metastases. She was apparently cured of this. Nine months before her second

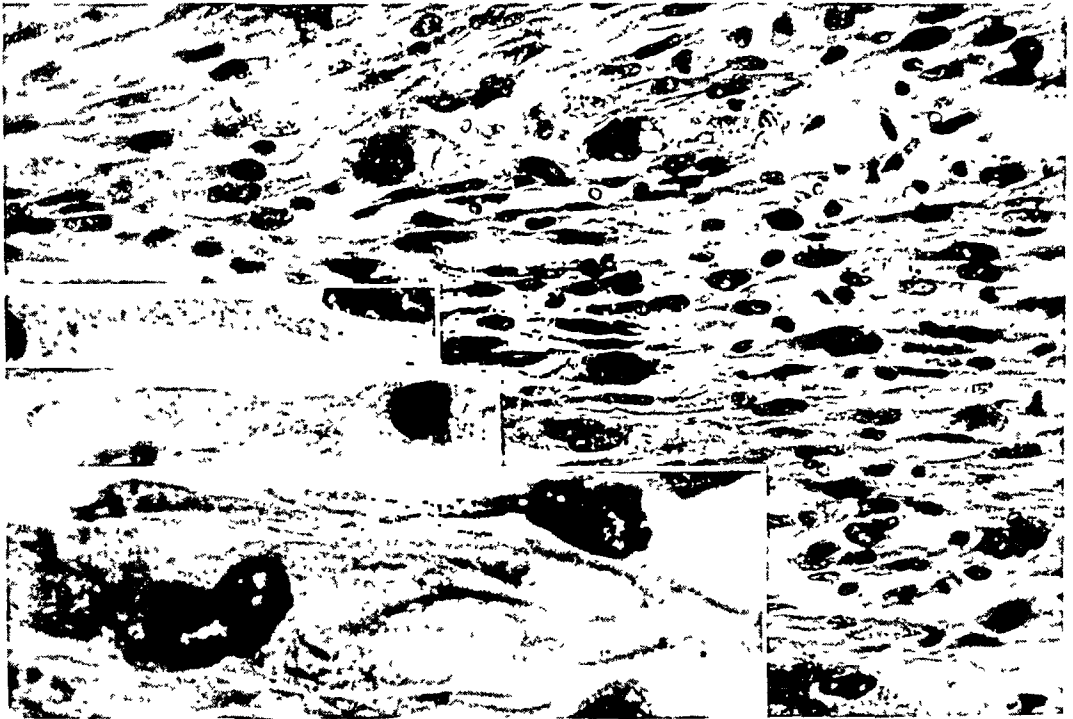


FIG. 4.—Case 4 (Table No. 111): Photomicrograph ( $\times 410$  and  $\times 1240$ ). Heidenhain's hematoxylin stain. The insets in the lower left corner show two strap cells with poorly defined cross-striations and two other cells with longitudinal myofibrils.

admission to the Presbyterian Hospital a painful swelling appeared on the outer aspect of the right forearm just caudad to the olecranon. It seemed to lie in the forearm muscles, was about 13.5 cm. in diameter and roentgenograms showed that it had eroded the outer condyle of the humerus probably by pressure. It was biopsied May 3, 1939. The woman refused all forms of treatment. The tumor slowly increased in size, ulcerated at the site of biopsy (Fig. 6) and she died at home approximately two and a half years after biopsy. Whether or not there were metastases is unknown.

*Microscopic* (S. P. 70542): The tumor is made up of bizarre large cells, amorphous usually but with strap syncytia formed occasionally. Giant forms are present but no spider cells. The cytoplasm is acidophilic and usually nongranular. Vague cross-striations are shown in some of the giant cells (Fig. 7).

**Case 8.**—(Table No. 115): M. A., a male, age 56. The only history available states that this man had a mass beneath his thigh muscles (*sic*) which was thought to be an hematoma. It was biopsied in October, 1916. In four months he was dead.

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*Microscopic* (P & S 3689): The tumor is made up of masses of large cells of extremely varied shape, including occasional strap forms with nuclei in tandem, and more giant cells with several nuclei near the center of the cell and vacuoles in the cytoplasm. The cytoplasm is sometimes granular. Very little fibrous framework. No longitudinal or cross-striations seen but the preparation is poor and there are no special stains.

**Case 9.**—(Table No. 116): Mrs. J. B., a white, American female, age 33. By chance the patient felt a lump in the right posteromedial brachial region and the next day consulted Dr. R. N. Schullinger. It was painless, rounded, and could be moved from side to side, but not from above downward. It was excised from within the belly of the triceps muscle March 3, 1932. Five years later there was no evidence of recurrence.



**FIG. 5.**—Case 5 (Table No. 112): Photomicrograph of rhabdomyosarcoma of back muscles. Heidenhain's hematoxylin stain ( $\times 410$  and  $\times 1240$ ). The highly magnified cell to the right shows longitudinal myofibrils and the two cells below contain granules which have an arrangement suggesting imperfect cross-striations.

**Gross** (S. P. 12245): A pallid, firm, pear-shaped encapsulated tumor  $2 \times 1 \times 1$  cm. The cut-surface showed a glistening white appearance with one small area of hemorrhage.

*Microscopic* (Fig. 8): Most of the tumor cells are small, amorphous or rounded cells with vacuolated cytoplasm. Scattered at intervals are larger rounded cells with strongly acidophilic cytoplasm which frequently show cross-striations. No longitudinal striations are seen. The nuclei are for the most part small and they do not have the sharply accentuated chromophilic markings of the more malignant and less well-differentiated rhabdomyoblastomas.

**Case 10.**—(Table No. 117): L. W., a male, age not stated. Eighteen months before a growth first appeared beneath the skin of the forearm. After one year it was excised but it soon reappeared, and in six months it measured  $9 \times 6 \times 3$  cm. Its surface was ulcerated. A biopsy was taken June 14, 1933, by Dr. R. N. Schullinger. The subsequent course is not known.



FIG. 6—Case 7 (Table No. 114): Rhabdomyosarcoma of forearm showing biopsy site.

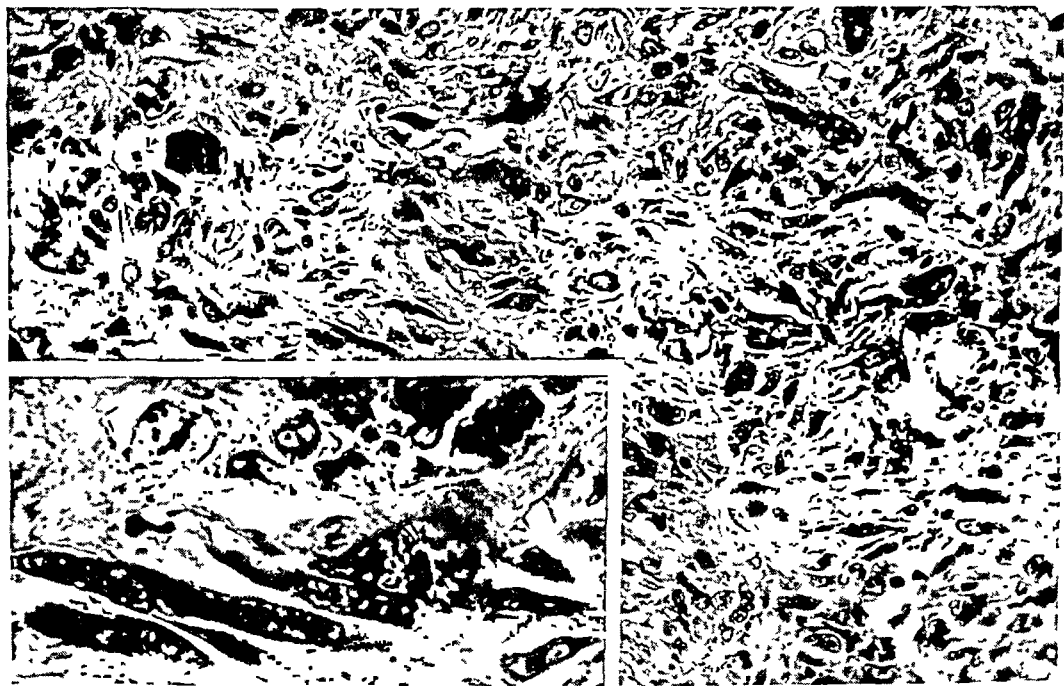
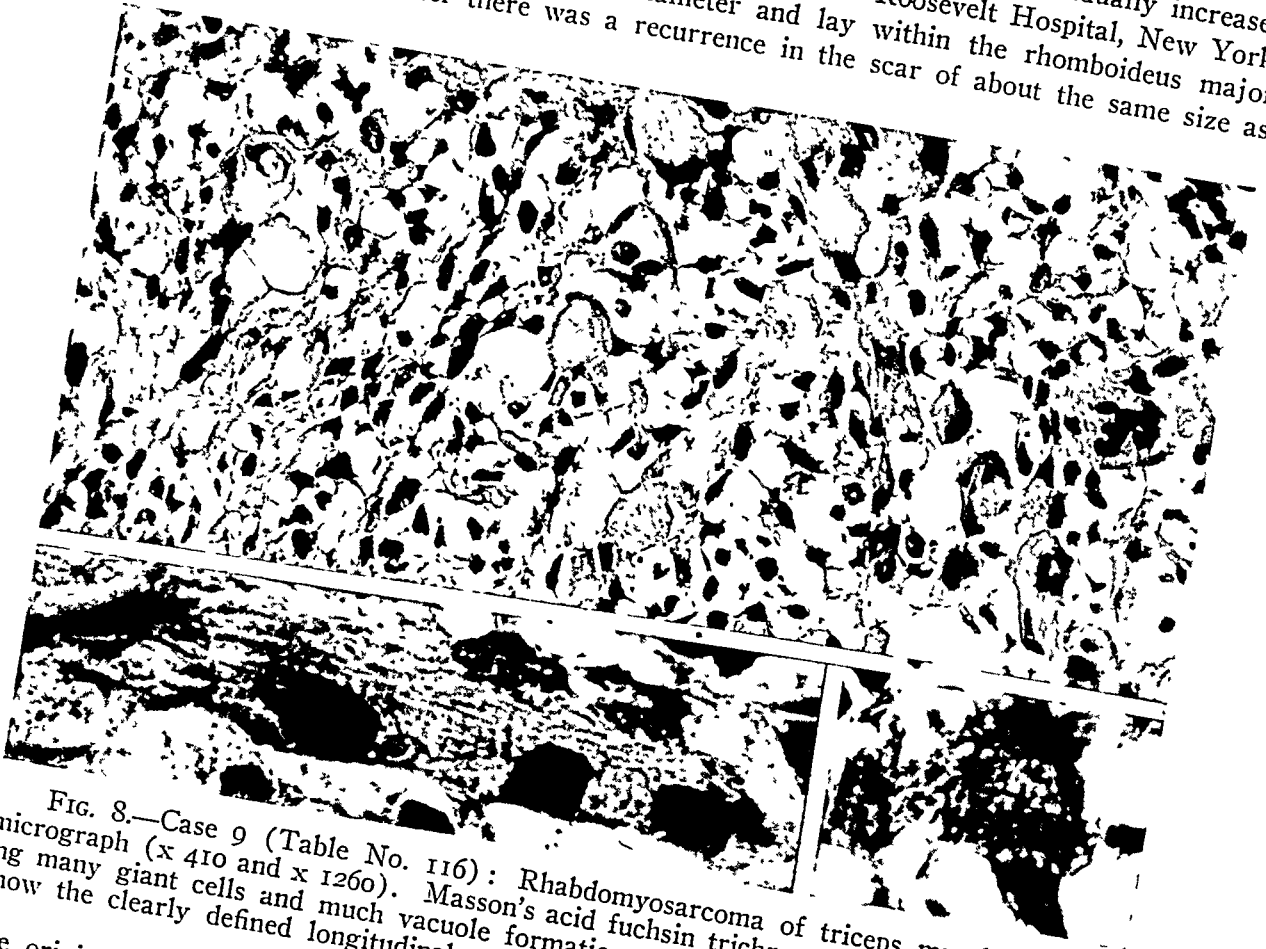


FIG. 7.—Case 7 (Table No. 114): Photomicrograph ( $\times 410$  and  $\times 1260$ ). Masson's acid fuchsin trichrome stain. The highly magnified inset in the lower left corner shows a strap cell with nuclei arranged in tandem and a giant cell with cross-striations faintly shown.

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*Microscopic* (P & S 12931): The biopsy is very small and from the surface. It shows a very edematous tumor in which the cells are widely separated. They are usually elongated and either have the nucleus at one end or two or more nuclei in tandem. Occasional small giant cells are seen. The cytoplasm is strongly acidophilic and either edematous or vacuolated. No definite longitudinal or cross-striations are seen.

**Case 11.**—(Table No. 118): F. H., a white, American schoolgirl, age 15 years. About six months before treatment she first complained of vague pain in the left shoulder region. Some three months later a lump appeared in this area and gradually increased in size. It was excised by Dr. William C. White at the Roosevelt Hospital, New York, February 3, 1939. It was 7 cm. in diameter and lay within the rhomboideus major muscle. Two years later there was a recurrence in the scar of about the same size as



**FIG. 8.**—Case 9 (Table No. 116): Rhabdomyosarcoma of triceps muscle. Photomicrograph ( $\times 410$  and  $\times 1260$ ). Masson's acid fuchsin trichrome stain. An area showing many giant cells and much vacuole formation. The highly magnified insets below show the clearly defined longitudinal and cross-striations in some cells.

the original tumor. This was widely removed, the excision including both rhomboid muscles. Roentgenograms of the chest at this time were negative. Doctor White reports that the girl was married in January, 1945, and was well at the beginning of June, 1945, 76 months after the first operation and 51 months after the second. Both of the specimens were examined by Dr. W. W. Brandes, pathologist of the Roosevelt Hospital, who recognized the neoplasm as a rhabdomyosarcoma.

*Microscopic* (P & S 16658): The original tumor shows long tapering cells with strongly acidophilic cytoplasm sometimes showing cross-striations but no longitudinal fibers. These are collected into bundles and interlarded with occasional rounded cells of somewhat larger size with acidophilic cytoplasm but no cross-striations (Fig. 9).

**Case 12.**—(Table No. 119): A male, age 53. Two weeks before he noted masses in the right axilla which measured  $2 \times 4$  cm. A biopsy was taken in April, 1939, at the Clifton Springs Sanitarium, at Clifton Springs, N. Y., and the section was submitted to this laboratory by Dr. W. C. Sternbergh, at that time connected with the Radiologic Department of the sanitarium.



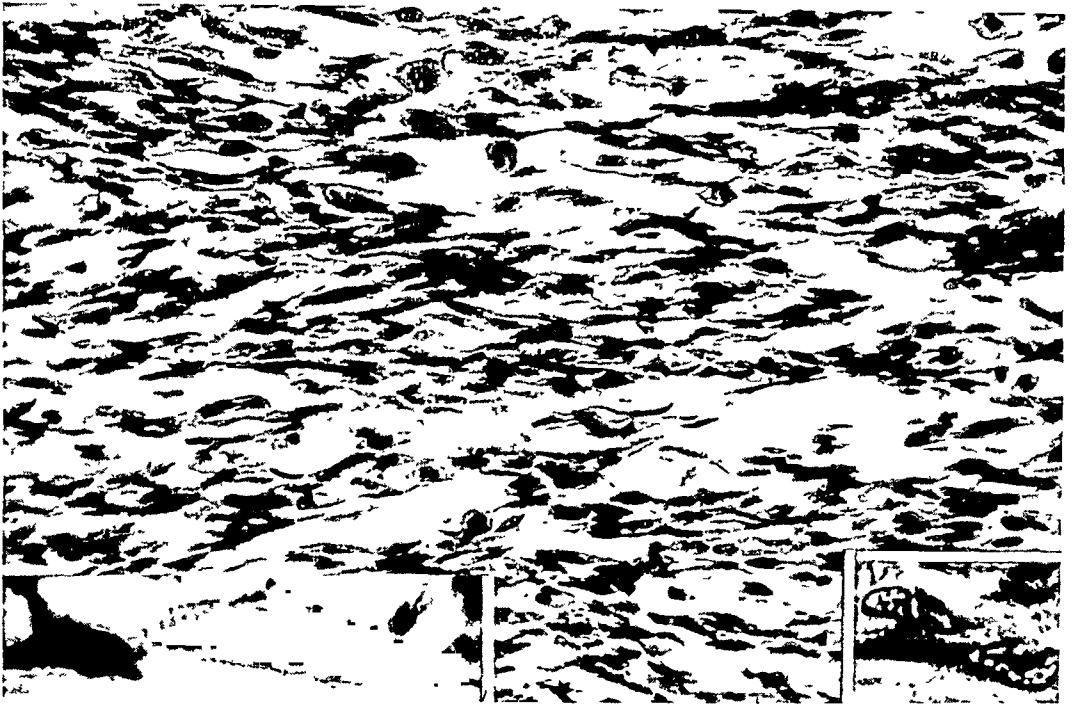


FIG. 9.—Case 11 (Table No. 118): Rhabdomyosarcoma of rhomboideus muscle. Photomicrograph ( $\times 410$  and  $\times 1260$ ). Masson's acid fuchsin trichrome stain. The highly magnified insets below show two tumor cells with clearly defined cross-striations.

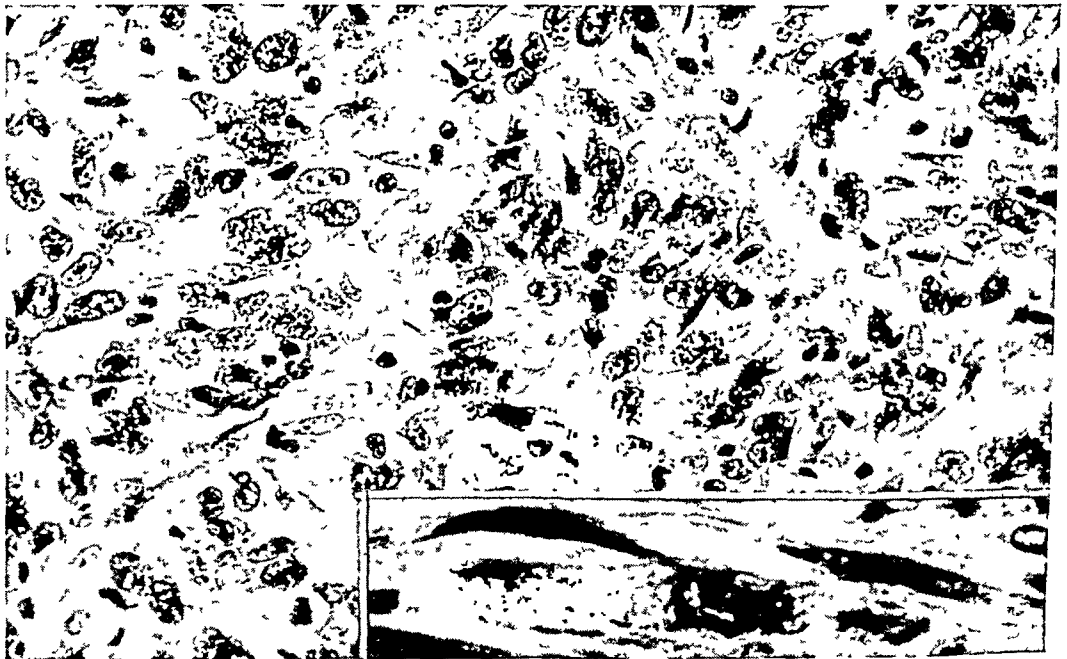


FIG. 10.—Case 12 (Table No. 119): Rhabdomyosarcoma of axilla. Photomicrograph ( $\times 410$  and  $\times 1260$ ). Masson's acid fuchsin trichrome stain. The highly magnified inset below shows two cells with faint poorly defined cross-striations.

*Microscopic* (P & S 16699) : The tumor is made up of many very large amorphous to rounded syncytial masses with one or more large hyperchromatic nuclei and clearly defined nuclear markings. Some are vacuolated. Strap cells are also present but uncommon. Rather vague cross-striations but no definite longitudinal fibers are found. The cells have cytoplasm which varies from neutrophilic to strong acidophilic (Fig. 10).

Case 13.—(Table No. 120) : M. G., a 69-year-old male Mexican. Eleven months before admission, following a strain from lifting a heavy object, a mass appeared in the right anterior axillary line. After five months it was the size of an orange and was excised. It recurred in the scar and when removed the second time it measured 8.5 x 5.5 x 7 cm., and could be moved over the fourth, fifth and sixth ribs. Fifty milligrams of radium

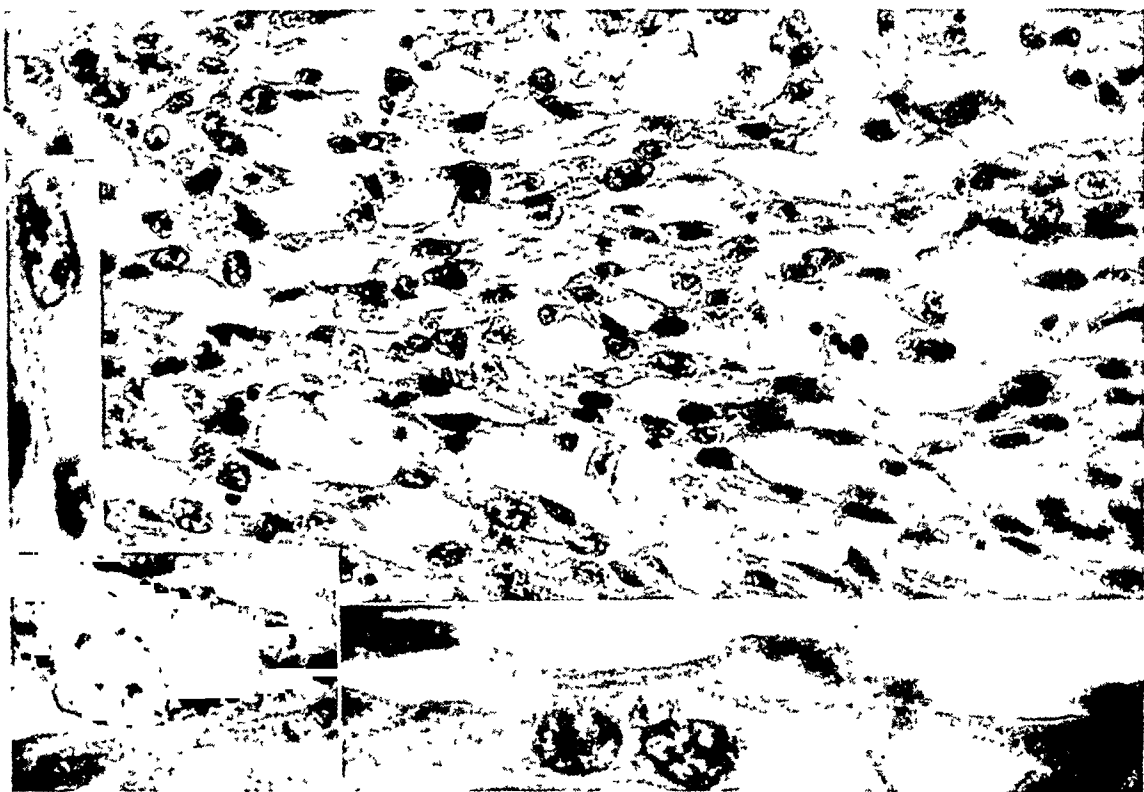


FIG. 11.—Case 13 (Table No. 120) : Rhabdomyosarcoma of anterior chest wall muscles. Photomicrograph (x 410 and x 1260). Masson's acid fuchsin trichrome stain. The highly magnified cells below and to the left show strap cells and a giant cell with faintly defined cross-striations.

was put in the wound. When cut open the tumor was soft, light pinkish-gray with darker areas of necrosis. He died six months later. The material was submitted by Dr. A. O. Severance of the Nix Laboratories, San Antonio, Texas.

*Microscopic* (S. P. 17403) : The tumor is made up of long slender strap cells with strongly acidophilic cytoplasm and some giant cells of small size. Cross-striations are demonstrated with difficulty (Fig. 11), but no longitudinal fibers are found.

Case 14.—(Table No. 121) : M. R., a female, age 66. Two years and eight months before operation she noticed a small purple nodule on the medial aspect of the right foot at the arch. It grew slowly beneath intact skin. It was only occasionally painful. It was locally excised, but recurred three months later and continued to grow for 11 months, forming a large fungating ulcerated mass (Fig. 12). This time the foot was amputated at the Ellis Fischel State Cancer Hospital, Columbia, Mo. I am indebted to Dr. Lauren V. Ackerman, Director of the Hospital, for the gross photograph and the sections.

*Microscopic* (S. P. 23294) : The tumor is made up largely of long slender cells resembling fibroblasts which grow in bundles accompanied by well-developed collagen and

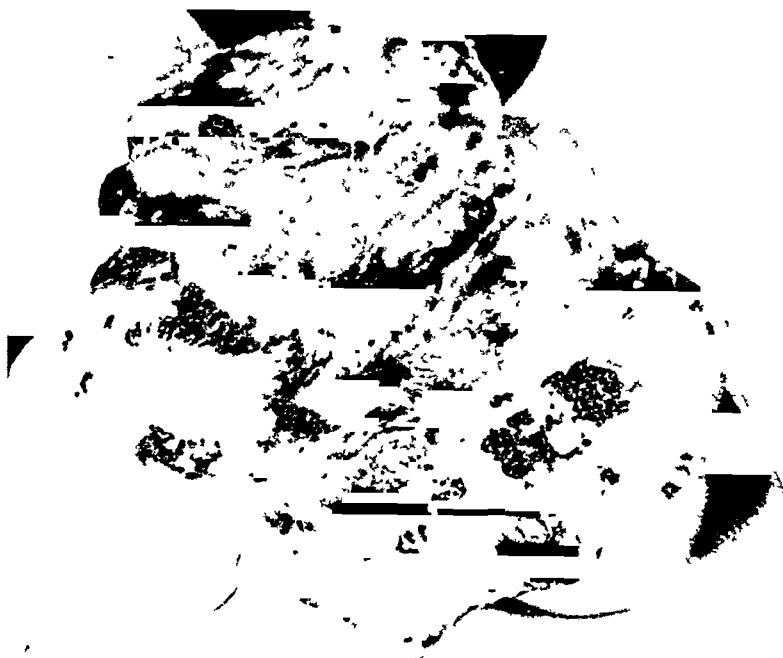


FIG. 12.—Case 14 (Table No. 121) : Rhabdomyosarcoma of the foot.

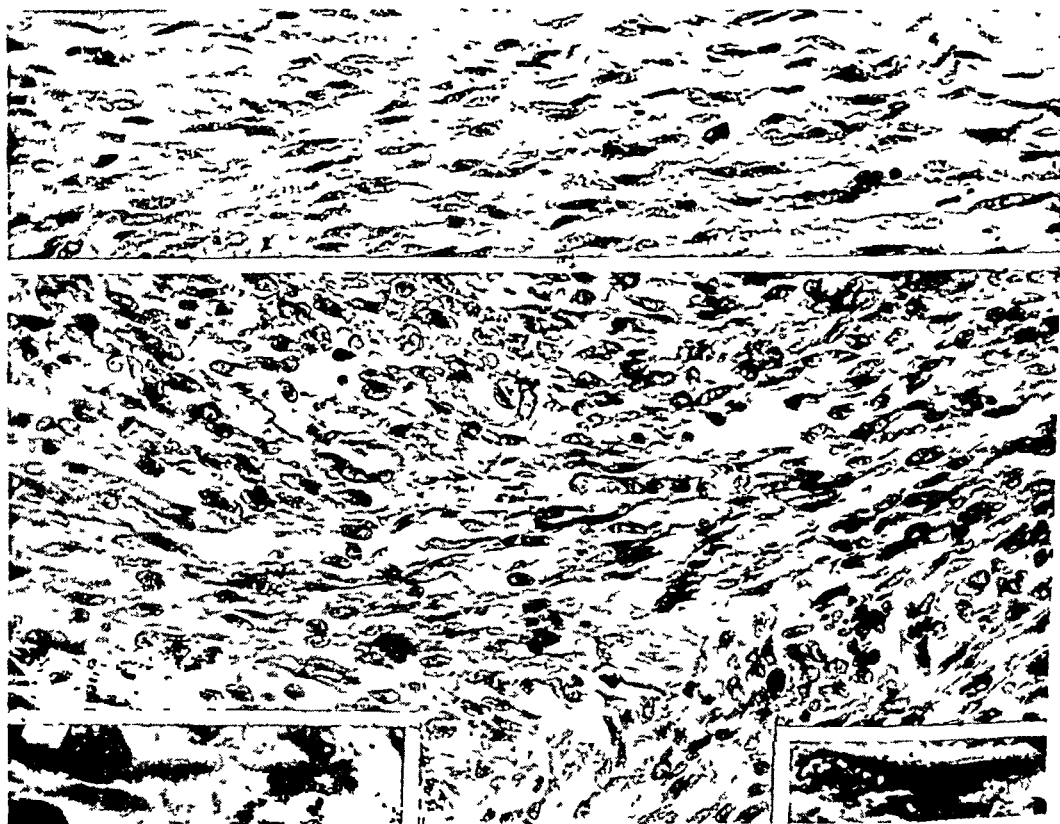


FIG. 13.—Case 14 (Table No. 121) : Photomicrograph ( $\times 410$  and  $\times 1260$ ). Masson's acid fuchsin trichrome stain. At the top is shown the fibrosarcoma-like area, below the less fibrous area with many strap cells. The highly magnified cells at the bottom with cross-striations were found in the latter area.

reticulin fibers. In one area there are fewer connective tissue fibers, the cells are more plump, and sometimes rounded. With Masson's trichrome stain it is possible to recognize that the cytoplasm of some of these cells is strongly acidophilic and that there are clearly defined cross-striations in a few of the small, plump, elongated cells and racquet-shaped forms. With the other stains used (eosin methylene blue and phosphotungstic acid hematoxylin) these features are so inconspicuous that they could very easily pass unnoticed (Fig. 13).

*Summary.* This study shows that, perhaps because it is so rare or so seldom recognized, painfully little information has accumulated in the past 90 years about rhabdomyosarcoma of the peripheral muscles. It is very difficult to form any clear mental picture of a tumor so variable that in one instance the clinical course from onset of symptoms until death was only two months (Case 90), while in another the tumor still persisted after 50 years (Case 38). Microscopically, the tumor is characterized by the presence of strap and racquet-shaped cells in which it is sometimes possible in good preparations to demonstrate cross-striations and longitudinal myofibrils, and by giant cells with peripherally arranged vacuoles causing the cell to resemble a spider or spider web. The cytoplasm of all these cells is more or less strongly acidophilic. Grossly, the tumors are found in or adjacent to striated muscles in various parts of the body but most commonly in the thigh and leg. The size is very variable but they seldom reach very great dimensions. The consistency also is variable but as they do not have a very high content of collagen, they are not apt to be extremely hard. Invariably, they infiltrate insidiously and metastases through the blood and lymphatic channels are not uncommon (31.5 per cent), with the lungs as the most favored repository. Records of only four symptom-free five-year survivals are reported among the 121 cases, 108 of which received treatment. One of these was treated by amputation alone, one by excision alone, and the other two by excision and radiotherapy. It should be noted, however, that long survivals of from nine to 50 years, with persisting tumor, are reported. If this tumor is to be cured more often, it is evident that extensive removal of the primary growth must be done earlier and more drastically with greater sacrifice of grossly healthy tissues about the growth. This need not always mean amputation. The writer feels very strongly that tumors of the soft-parts and bones should not be attacked without preliminary biopsy. If this is done carefully there should be no danger of tumor metastasis. Armed with a knowledge of the nature of the growth the most advantageous therapeutic procedure can then be selected.

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## ANNOUNCEMENT

### UROLOGY AWARD

UROLOGY AWARD.—The American Urological Association offers an annual award "not to exceed \$500" for an essay (or essays) on the result of some specific clinical or laboratory research in Urology. The amount of the prize is based on the merits of the work presented, and if the Committee on Scientific Research deem none of the offerings worthy, no award will be made. Competitors shall be limited to residents in urology in recognized hospitals and to urologists who have been in such specific practice for not more than five years. All interested should write the Secretary, for full particulars.

The selected essay (or essays) will appear on the program of the forthcoming meeting of the American Urological Association, to be held at the Netherland Plaza, Cincinnati, Ohio, July 22-25, 1946.

Essays must be in the hands of the Secretary, Dr. Thomas D. Moore, 899 Madison Avenue, Memphis, Tennessee, on or before July 1, 1946.

Committee on Scientific Research

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# SUPRACONDYLAR AMPUTATIONS

## A SURVEY

M. J. TOBIAS, M.D.

NEW YORK, N. Y.

FROM THE SURGICAL SERVICES, GOLDWATER MEMORIAL HOSPITAL, N. Y., DR. WILLIAM HOWARD BARBER, DIRECTOR  
3RD SURGICAL DIVISION, AND DR. GRANT P. PENNOYER, DIRECTOR, 2ND SURGICAL DIVISION.

THE FOLLOWING SURVEY covers the results of 149 amputations undertaken on 131 patients on all Surgical Services of the Goldwater Memorial Hospital between July 1, 1939, and January 1, 1945. The great majority of cases are thigh amputations. Of the 16 leg amputations, eight were subsequently submitted to supracondylar procedures. Abbreviations (see Table I) are employed to denote the general classification of the patients. As a result of this study, certain modifications in present procedures in the management of such cases is indicated.

No attempt has been made to outline the severity of the individual case, nor the gravity of its complications. The latter are so varied in their manifestations that they fully deserve separate treatment. Moreover, it should be taken for granted that these patients are all gravely ill and borne down not only by the occlusive vascular disease which leads to the amputation, but also by the manifold complications of generalized arteriosclerosis and of diabetes, or both. Nor are they free from the neoplastic diseases common to this age-group. Nevertheless, in order to indicate the general order to which each patient belongs, we have confined their classification to four groups: arteriosclerosis, diabetes, thrombo-angiitis obliterans, and others. (See Table V.)

Since patients of this age-group (see Tables I, II, III and V) who suffer from diabetes are never free from arteriosclerosis in one or all of its manifestations, all patients under this classification may be considered arteriosclerotics whose disease is complicated by diabetes.

The advent of refrigeration as a form of anesthesia, particularly in view of some enthusiastic reports of its efficacy and life-saving potentialities, quite naturally challenges a comparison between it and the older methods. With this in mind, I have grouped the results of our amputations into Refrigeration, Spinal, and Cyclopropane, according to the method of anesthesia employed.

The results obtained are tabulated in Tables I, II and III. The findings in Table IV indicate (a) that the mortality under refrigeration is almost twice that of either of the other methods; and (b) that not only is the incidence of gas bacillus infection high under refrigeration, but also that this form of infection did not occur at all with the other methods.

These findings prompted a search of the literature for results obtained by other clinics, and the latter, as far as I could gather, are shown in Table VI.

Some of the authors accentuate the fact that refrigeration was used only on the gravely ill, and in certain instances they even attempt—for the sake



TABLE I  
REFRIGERATION ANESTHESIA

Recoveries						Deaths					
No.	Name	Age	General Classif.	Extremity	Days P-Op.	No.	Name	Age	General Classif.	Extremity	Days P-Op.
1	H. B.	79	As	L thigh	12(?)	49	P. S.	76	Di	R thigh	60(G)
2	M. M.	74	Di	L thigh	18	50	R. A.	67	Di	R thigh	21
				R thigh	34(G)	51	M. A.	72	Di	L thigh	89
3	A. M.	69	Di	R thigh	105(G)	52	H. C.	50	Di	L thigh	17
4	G. B.	70	Di	L thigh	160	53	J. F.	75	Di	R thigh	21
5	A. S.	59	Di	R thigh	160	54	J. K.	85	As	L thigh	2(G)
6	T. C.	62	As	R leg		17	M. S.	76	As	R thigh	10
				R thigh	28	55	A. T.	80	As	R thigh	1
7	S. B.	57	Di	L thigh	66	56	R. W.	68	Di	L thigh	63(G)
8	J. F.	79	Di	R thigh	32	57	J. N.	70	Di	L thigh	105
9	C. H.	54	As	R thigh	240	58	S. R.	65	Di	L thigh	130
10	S. L.	64	Di	L leg		59	B. P.	71	As	R thigh	7
				L thigh	44	60	L. R.	70	As	R thigh	4
11	W. K.	60	Di	R leg	61	61	F. M.	75	Di	L thigh	32
12	S. duB.	60	As	L thigh	148(G)	62	M. McG.	76	Di	R thigh	On op. table
13	J. G.	56	As	R thigh	66	63	H. W.	58	Di	R thigh	13
14	J. H.	70	Di	R thigh	67	64	C. S.	61	Di	R thigh	11
15	J. Gr.	74	As	R thigh	135	65	J. G.	62	Di & THR	L thigh	23
				L leg	204	66	S. DeB.	62	As & Ost	R thigh	2
16	G. S.	85	As	L thigh	26	67	A. A.	61	Di	R thigh	3
17	M. S.	76	As	L leg		68	N. B.	48	Di	L leg	54
				L thigh	48(G)	69	J. B.	81	As	L thigh	4
18	M. V.	43	As	L thigh	10(?)	70	P. C.	71	As & THR	L thigh	1
				R thigh	15(?)	71	J. C.	75	As	R thigh	91
19	A. O.	57	Di	L thigh	107(G)	72	I. F.	61	As	L leg	(See Cyclo) (G)
20	E. G.	44	TAO	R thigh	31	36	M. G.	57	As	R thigh(2)*	131
				L thigh	35	73	J. H.	77	As	R thigh	5
21	C. M.	68	As	R thigh	104	74	H. H.	61	As	L thigh	22
22	J. M.	75	Di	L thigh	66	75	R. K.	72	As & THR	L thigh	25
23	G. R.	83	As	R leg	60	76	A. W.	72	As	R thigh	1
24	C. S.	65	As	R thigh	37	77	T. McC.	74	As	R leg	
25	K. S.	61	Di	L leg	47				R thigh	17	
26	M. O.	75	Di	R thigh	8(?)	78	M. M.	77	Di	L thigh	5
27	W. C.	67	Di	R thigh	60	79	C. M.	71	As	R thigh	1
28	K. V.	70	Di	R thigh	12(?)	80	F. R.	75	Di	L thigh	30
29	J. B.	74	Di	R leg	106	81	O. W.	78	As	R thigh	23
30	C. C.	72	As	R thigh	96	82	L. McM.	62	As	R thigh	116
31	J. F.	62	As	R thigh	42	83	G. B.	79	Di	R thigh	1
32	M. F.	50	Di	L thigh	12(?)						
33	F. E.	60	As	R thigh	56						
34	T. F.	60	Di	L thigh	31						
35	R. G.	68	As	L thigh	7(?)						
36	M. G.	57	As & THR	L thigh(1)*	78						
37	G. H.	69	Di	L thigh	28						
38	M. H.	36	L-Ed	L thigh	150						
39	L. K.	70	Di	L thigh	7(?)						
40	J. L.	72	As	L thigh	17						
41	L. M.	54	Di	R thigh	15						
42	W. P.	61	As	L thigh	50						
43	O. S.	57	As	R thigh	48						
44	J. M.	61	As	L thigh	9(?)						
45	A. S.	70	Di	R thigh	242						
46	H. B.	73	As	L thigh	30						
47	V. L.	66	As	R thigh	16						
48	P. H.	74	Di	R leg	122						

SUMMARY OF AMPUTATIONS UNDER  
REFRIGERATION ANESTHESIA

Total number of amputations.....	94
(performed upon 83 patients)	
Total number of deaths.....	36
Amputation mortality.....	38.2%
Case mortality.....	43.3%
Total number of gas infections.....	9
Amputation incidence.....	9.57%
Case incidence.....	10.84%

\* (1) indicates the first operation; and (2) the second operation.

## Abbreviations:

As = Arteriosclerosis Di = Diabetes TAO = Thrombo-angiitis obliterans THR = Thrombosis of chief  
artery L-Ed = Lymphedema, chronic (etiology not established) Sp.Par = Spinal paraplegia  
Polio = Poliomyelitis (G) = Gas bacillus infection (*Cl. welchii*) (?) = Records incomplete as to  
exact date of stump-healing

# SUPRACONDYLAR AMPUTATION

of the record—to attribute a fatality to a preëxisting disease or to its complication. This would seem a difficult and controversial way to classify success and failure. To us it appeared sufficient to classify a case as a failure when the patient, at death, *showed an unhealed stump*, with varying degrees of infection, suppuration or gangrene, regardless of preëxisting disease or length of the postoperative survival period. On the other hand, all cases with healed stumps were set down as recoveries, although a goodly number subsequently succumbed to preëxisting or other disease.

TABLE II  
SPINAL ANESTHESIA

Recoveries						Deaths					
No.	Name	Age	General Classif.	Extremity	Days P-Op.	No.	Name	Age	General Classif.	Extremity	Days P-Op.
84	J. B.	74	As	R thigh	14	93	J. B.	76	As	R thigh	2
85	C. C.	38	TAO	L leg	57	94	A. R.	81	Di	R thigh	8
86	C. G.	74	As	R thigh	17	95	M. W.	62	As	L thigh	2 hrs.
87	J. H.	73	As	L thigh	16	96	C. M.	77	Di	R thigh	18
88	J. J.	66	As	R thigh	64	97	L. G.	72	As	L thigh	14
89	M. R.	66	As & THR	L thigh	9						
90	J. R.	66	As	R leg	391						
91	W. C.	79	As	L thigh	31						
92	G. C.	43	As	L leg(2)*	14						
98	K. D.	69	As	L thigh	11						
15	J. Gr.	74	As	L thigh	91						
99	M. M.	55	As	L thigh	35						

\*(2) indicates the second operation.

## SUMMARY OF AMPUTATIONS UNDER SPINAL ANESTHESIA

Total number of amputations.....	17 (performed upon 17 patients)
Total number of deaths:.....	5
Amputation mortality.....	29.4%
Case mortality.....	29.4%
Total number of gas infections.....	0

Some authors, again, compare the results obtained under refrigeration with those of some ten years ago, under the then prevailing methods. They find solace in the infinitely lower death rate now obtained by refrigeration, forgetting, for the moment, the immense contributions made to surgery by the sulfa drugs, penicillin, polyvalent sera, and a great number of other drugs and measures employed at the present time in pre- and postoperative care. This is exemplified in the results we obtained under cyclopropane (see Table III).

A review of some of the literature follows. In no instance did the results obtained under refrigeration, whenever the Allen technic was used, equal those reported by the originators of the method who, indeed, reported a case mortality of 15.5 per cent (see Table VI, 1).

Captain Shaar and coworkers<sup>2</sup> report ten cases under refrigeration, with two deaths, a case mortality of 20 per cent. They are very enthusiastic about this method, although in the same place they report 37 cases under spinal with one death, which yields a mortality of only 2.6 per cent. No mention is made of gas gangrene.

TABLE III

## CYCLOPROPANE ANESTHESIA

Recoveries						Deaths					
No.	Name	Age	General Classif.	Extremity	Days P-Op.	No.	Name	Age	General Classif.	Extremity	Days P-Op.
100	R. J.	73	Di	R thigh	95	125	J. B.	70	Di	L thigh	11
101	A. L.	59	Di	R thigh	122	72	I. F.	61	As	L thigh	56
102	J. A.	50	As	L thigh	15	126	W. K.	64	As	L thigh	2
103	J. R.	64	Sp.Par.	L thigh	7(?)	127	E. K.	77	Di	R thigh	9
				R thigh	8(?)	128	E. P.	77	As	L thigh	21
104	M. B.	67	Di	R thigh	95	129	J. R.	82	As	L thigh	10
105	G. C.	65	Di	L thigh	90	130	J. S.	72	As	R thigh	11
106	A. DeC.	68	Di	R thigh	41	131	D. C.	66	As	R leg	23
107	E. D.	61	As	L leg	561						
				L thigh							
92	G. C.	43	As	L leg(1)*	424						
				L thigh(3)*							
108	O. E.	84	As	L thigh	75						
109	M. E.	16	Polio	R thigh	13						
110	M. F.	62	As	R thigh	84						
111	S. G.	73	Di	R thigh	17						
112	J. G.	64	As	L thigh	25						
113	D. K.	57	Di	R thigh	66						
114	P. L.	47	As &	L leg	10						
			frostbite								
82	L. McM.	62	As	L thigh	66						
115	V. LaM.	61	As	L thigh	15						
116	V. M.	52	TAO	R thigh	21						
117	Y. R.	58	Di	R thigh	69						
118	M. P.	72	As	L thigh	76						
119	S. S.	60	As & THR	R thigh	45						
120	F. R.	77	As	L thigh	15						
121	C. St.M.	82	As	R thigh	40						
122	W. S.	78	Di	L thigh	69						
123	J. W.	38	As	R thigh	18						
124	J. S.	50	TAO	R thigh	9(?)						

\*(1) indicates the first operation; and (3) the third operation.

## SUMMARY OF AMPUTATIONS UNDER CYCLOPROPANE ANESTHESIA

Total number of amputations.....	38 (performed upon 35 patients)
Total number of deaths:.....	8
Amputation mortality.....	21.05%
Case mortality.....	22.83%
Total number of gas infections.....	0

TABLE IV

## SUMMARY

Anesthesia Employed	No. of Amputations	No. of Patients	No. of Deaths	Amp. Mort.	Case Mort.	No. of Gas Inf.	Gas Bac. Inf.	
							Amp. Incid.	Case Incid.
Refrigeration.....	94	83	36	38.2%	43.3%	9	9.57%	10.84%
Spinal.....	17	17	5	29.4%	29.4%	0	0	0
Cyclopropane....	38	35	8	21.05%	22.85%	0	0	0

TABLE V

## CLASSIFICATION OF PATIENTS

	Average Age	Total No.	No. of Deaths	Case Mortality
Diabetic males.....	65.8	24	8	33.3%
Diabetic females.....	66.7	30	14	46.6%
Arteriosclerotic males.....	68.5	54	17	31.2%
Arteriosclerotic females.....	66.6	16	10	62.5%
Thrombo-angiitis obliterans.....	46.0	4	0	0
Others.....		3	0	0

Glasser and Mersheimer<sup>3</sup> report 17 amputations under refrigeration, with a case mortality of 38.8 per cent (Table VI, 3).

O'Neill<sup>4</sup> (Table VI, 4) reports 50 cases under refrigeration, with a case mortality of 32 per cent, and an incidence of gas gangrene of 4 per cent.

Cayford and Pretty<sup>5</sup> (Table VI, 5) report 22 amputations, with a case mortality of only 18 per cent, and a gas infection incidence of 13.6 per cent.

TABLE VI  
CASE REPORTS FROM OTHER CLINICS

1. Crossman, Ruggiero, Allen, <i>et al.</i> <sup>1</sup>			
57 amputations (upon 45 patients) under refrigeration			
Number of deaths: 7			
Amputation mortality.....	12.2%		
Case mortality.....	15.5%		
Gas gangrene infections: 1 case—Incidence.....	2.2%		
2. Captain Shaar and a group of Naval Officers <sup>2</sup>			
53 amputations, as follows:			
37 cases under spinal, with 1 death; case mortality.....	2.6%		
10 cases under refrigeration, with 2 deaths; case mortality.....	20.0%		
5 cases under local, with 1 death; case mortality.....	20.0%		
No mention is made of gas gangrene			
3. Glasser and Mersheimer <sup>3</sup>			
17 amputations under refrigeration, with a case mortality of.....	38.8%		
No mention is made of gas gangrene			
Pneumonia and pulmonary embolism are cited as frequent causes of death in this group			
4. O'Neill (Boston City Hospital) <sup>4</sup> reports the following.			
	No. of Cases	No. of Deaths	% Mortality
Unoperated cases 1930-39.....	162	162	100%
Operated cases 1930-39.....	270	142	53%
Unoperated cases 1940-43.....	4	4	100%
Operated with refrigeration 1940-43.....	50	16	32%
Gas gangrene, 2 cases*—Case incidence: 4%			
* Early in series. Since then, every case gets polyvalent serum preoperatively. Dr. O'Neill imputes that if not for this precaution, incidence of gas bacillus infections would be higher.			
5. Cayford and Pretty <sup>5</sup>			
22 amputations, with 4 deaths: Case mortality.....	18%		
Gas bacillus infections: 3; Case incidence.....	13.6%		
Note: Refrigeration without tourniquet was used in 18 of the above cases, according to a modification of the McElvenny method.			
6. McElvenny <sup>6</sup>			
6 cases—No. of deaths: 1; Case mortality.....	16.6%		
Refrigeration without tourniquet, or freezing			
7. Large and Heinbecker <sup>7</sup>			
6 cases—No. of deaths: 0; Case mortality: 0			
Note: Refrigeration plus tourniquet according to new concept based on laboratory evidence on the advantages and disadvantages of refrigeration			

But, here, it should be noted that in 18 of the above cases, refrigeration alone, *without a tourniquet*, was employed.

McElvenny<sup>6</sup> (Table VI, 6) reports six cases with one death. This author, in the main, has discarded the tourniquet and uses either refrigeration alone or freezing of the affected limb, without relying on either one for anesthesia during amputation.

Large and Heinbecker<sup>7</sup> (Table VI, 7) report six cases with no deaths, employing refrigeration plus tourniquet, according to a new concept.

The concepts of Doctor Allen, in the main, were accepted. Certain of his contentions, however, particularly with reference to tissue damage under refrigeration, are challenged.

Richards,<sup>8</sup> of Stanford University, on the basis of two clinical cases, offers microscopic proof of damage to muscle, nerve, and blood vessels, of tissues submitted to refrigeration. Of particular interest, in addition, are the conclusions of Richards, which he reached with reference to one of these cases. The latter was a 52-year-old diabetic female who had suffered an embolic occlusion of the left femoral artery. Embolectomy failed to restore the circulation to the limb, and it was decided to submit the limb to refrigeration in order to reduce its metabolic requirements to a minimum, thus affording opportunity for the possible development of an adequate collateral circulation.

For 13 days, the thigh was maintained at an approximate skin temperature of 18° C., and the leg at 8° C., without a tourniquet. Although true gangrene of the limb did not occur and infection did not appear, it became obvious on the 13th day that the limb was not viable, and a guillotine amputation, under refrigeration, was performed. Twenty-two days postoperative, there was no closure of the stump wound, and the patient died exhibiting the symptoms of either acute heart failure or pulmonary embolus. Postmortem was not obtained.

The amputated limb was gangrenous, but infection of the tissues and necrotic changes were minimal. The popliteal vessel was occluded by an organizing thrombus. "As soon as the thrombus was removed it was apparent the blood had not coagulated in the peripheral structures, for a radiopaque mass could be easily injected into the popliteal vessels and made to flow down the leg. Even the minutest vessels of the foot were patent. However, microscopic studies of the muscle, nerve, blood vessels and skin of the amputated limb were discouraging, for they showed degeneration above referred to."

Doctor Richards remarks: "This isolated experience of a limb which was the seat of an unsuccessfully removed arterial embolus was not gratifying. Although cooling of the anoxic limb had retarded the metabolic needs of the tissues and prevented gross necrotic changes, we felt it had not prevented gangrene, had caused the available collateral blood vessels to contract, and had retarded both the stimulus for, and rate of, growth of new collateral channels."

Our knowledge of the action of refrigeration on normal tissues has recently been augmented by the experimental work of a group<sup>9, 10, 11</sup> from the Washington University School of Medicine and the Barnes Hospital, St. Louis, Mo. The results of their labors are summed up as follows:

1. During the refrigeration period, there is inhibition of the *inflammatory reaction response*, which becomes slightly greater during the period following refrigeration.

2. During the refrigeration period, there is *inhibition of response to Streptococcus hemolyticus*, while after refrigeration the tissues exhibit a *decreased* resistance to these bacteria.

3. *There is inhibition of wound healing*, the delay being roughly proportional to the duration of the cooling period, and, finally,

4. Wounds of refrigerated tissues showed a much higher incidence of *gross infection with suppuration* than did the uncooled controls.

In a recent article, Large and Heinbecker<sup>7</sup> offer a comprehensive review of the subject of refrigeration. These authors summate the advantages and disadvantages of refrigeration as well as the application of the tourniquet, as follows:

1. "The benefits of refrigerating an extremity include loss of sensation and diminution of absorption of noxious agents from the cooled area, while the disadvantages lie in a subsequent delay in wound healing, a greater risk of infection, and a varying degree of actual damage to refrigerated tissues left *in situ*.

2. "The benefits of the application of a tourniquet to a limb refrigerated *above* the proposed level of amputation include anesthesia and the elimination of absorption of noxious agents, with increased duration of viability, of the completely ischemic tissues, while the ill effects, again, include delayed wound healing, greater risk of infection, and actual tissue damage to the refrigerated stump.

3. "The benefits of refrigeration with the application of a tourniquet *below* the proposed level of amputation of a limb, as in other instances, include loss of sensation and elimination of absorption of noxious agents from the part; the further advantage of eliminating delay in wound healing and the spread of infection also is assured."

Large and Heinbecker<sup>7</sup> also mention that the disadvantage of the Allen method appears to lie in the fact that much of the cooled and, therefore, damaged tissue is not excised; they recommend that all refrigerated tissue should be removed at operation, and show that this can be done *by applying the tourniquet and the cold distal to the level of amputation*.

The results obtained with the present series of cases under refrigeration according to the Allen technic appear to corroborate, clinically, the deductions put forward by Large, and coworkers. In addition, one is impelled to the conclusion that the high incidence of gas bacillus infections in this series, as well as in that reported by Cayford and Pretty,<sup>5</sup> and O'Neill,<sup>4</sup> may be explained by the fact that an amputation stump, rendered anoxic by refrigeration and/or tourniquet, offers an ideal field for the growth of the obligate anaerobic *Clostridii*.

#### SUMMARY

1. The results of 149 amputations, the great majority supracondylar procedures, are reported.

2. The results, tabulated according to the form of anesthesia employed, show an amputation mortality of 38.2 per cent with refrigeration according to the Allen technic (Table I); an amputation mortality of 29.4 per cent under spinal (Table II); and an amputation mortality of 21.05 per cent under cyclopropane (Table III).

3. An amputation incidence of 9.57 per cent of gas bacillus infections occurred with refrigeration according to the Allen technic (Tables I and IV).

No gas bacillus infections occurred in either of the other groups (Tables II, III and IV).

4. The clinical results obtained under refrigeration in this hospital, as well as in some others<sup>3, 4, 5</sup> appear to corroborate the laboratory findings of Large and Heinbecker.<sup>10, 11</sup>

5. Modifications in procedure of refrigeration as applied to amputations, and suggested by Large and Heinbecker,<sup>7</sup> have been adopted and are now being carried out on a new group of cases. Although the results in this new group are good, the group as yet is too small to warrant conclusions or reporting.

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## TRANSACTIONS OF THE SOUTHERN SURGICAL ASSOCIATION

MEETING HELD AT HOT SPRINGS, VA.  
DECEMBER 4-6, 1945

### ADDRESS OF THE PRESIDENT

THE TRANSYLVANIA MEDICAL LIBRARY\*

CHARLES A. VANCE, M.D.  
LEXINGTON, KY.

I WOULD BE VERY REMISS in my obligation to you if I did not first thank you for the very great honor you have bestowed on me. To be elected your President is the greatest honor that can come to any surgeon, and I am expressing to you my very sincere thanks and appreciation.

Our association has shown considerable interest in surgery in Kentucky. At the Lexington meeting in 1930 there was conducted a pilgrimage to the tomb of Ephraim McDowell, in Danville, and addresses were made by our fellow members, Dr. Urban Maes and Dr. F. G. DuBose, and a wreath was placed on the grave. During that meeting a number of Fellows who visited the Transylvania Medical Library, were so impressed by the priceless collection of old medical volumes contained in the library that the following resolution was presented by Dr. J. M. T. Finney: "That we desire, first of all, to felicitate the University upon being the repository of such a unique collection. At the same time, we are greatly disturbed by the fact that, unfortunately, this collection is not housed in a fire- and theft-proof building. Feeling deeply that the loss to the profession at large, as well as in that of the Southland, which this association more closely represents, would constitute an irreparable loss, the Southern Surgical Association offers its services, in coöperation with the proper authorities, toward securing adequate protection.

To this end, it is moved that the President be instructed to appoint a com-

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\* Delivered before the Fifty-seventh Annual Session of the Southern Surgical Association, December 4-6, 1945, Hot Springs, Virginia.



mittee for this purpose." This matter was referred to the President and the Council, and a committee from the association was appointed. This committee included Doctors Abell and Vance, from Kentucky, and several others. A meeting or two was held but nothing much was done.

Personally, I have been interested in Transylvania University all my life. My grandfather, Robert A. Gibney, graduated at the Transylvania Medical Department in 1836. His Inaugural Dissertation, as it was called then, was on "Respiration," and my great uncle, my grandfather's brother, Thomas Carson Gibney, graduated there in 1841. His Inaugural Dissertation was on "Oscultation and Percussion." And a number of other members of my family attended and graduated at Transylvania, and I graduated there in 1900, so you see I have a personal interest in Transylvania.

Dr. Robert Peter says in his history of the Medical Department of Transylvania: "That the History of Medicine and of the earliest medical men in Kentucky clusters around the name of Transylvania University."

In 1780, the State of Virginia placed 8,000 acres of escheated land within the County of Kentucky into the hands of 13 trustees "for the purposes of a public school or seminary of learning," that there "might, at a future day, be a valuable fund for the maintenance and education of youth: it being the interest of this Commonwealth always to promote and encourage every design which might tend to the improvement of the mind and the diffusion of knowledge, even among the most remote citizens, whose situation, a barbarous neighborhood and a savage intercourse, might otherwise render unfriendly to science."

In 1783, after Kentucky had become a District of Virginia, the General Assembly, by a new amendatory act, reëndowed this public school with 12,000 acres of escheated lands and gave to it all the privileges, powers, and immunities of any college or university in the State under the name of "Transylvania Seminary." This was located permanently in Lexington on a plot of land donated by the City of Lexington in 1793, and Rev. James Moore was the first acting President in 1791. The name was derived from the Transylvania Land Company which Henderson had started several years before for the sale of lands in Kentucky.

Dissatisfaction with the conduct of Transylvania Seminary, among some of the members of the Board of Trustees, caused them to leave that school and obtain, in 1796, a Charter from the Legislature of Kentucky for a new institution of learning which they could more exclusively control. This was the Kentucky Academy, of which the Rev. James Blythe was made President. After two years of separate existence these two institutions, with the consent of the trustees of both, were united, in 1798, by Act of the General Assembly into one—"For the promotion of public good and learning," under the name of Transylvania University. This consolidation was made under the original laws which governed the Transylvania Seminary, as enacted by the General Assembly of Virginia.

Under this act of December 22, 1798, the University was organized by the appointment of the Rev. James Moore, of the Episcopal Church, as the first

acting President, with a corps of professors, and then, for the first time, in the Mississippi Valley and the West the effort was made to establish a Medical College.

Early in 1799, at the first meeting of the Board of Trustees of the new Transylvania University they instituted the Medical Department of Transylvania, which subsequently became so prosperous and so celebrated, by the appointment of Dr. Samuel Brown as Professor of Chemistry, Anatomy, and Surgery, and Dr. Frederick Ridgely as Professor of Materia Medica, Midwifery and Practice of Physic. Dr. Brown qualified as Professor October 26, 1799, and Dr. Ridgely the following month.

Doctor Brown was authorized by the Board to import books and other means of instruction for the use of the medical professors to the amount of 500 dollars, a considerable sum in those days, and he and his colleagues were made salaried officers of the University.

At a meeting of the Board of Transylvania Seminary, in 1784, they acknowledged the gift from the Rev. John Todd, of Louisa, in Virginia, of a Library and a Philosophical apparatus for the encouragement of science in this institution. There is frequent mention in subsequent minutes of the Board of its appropriation of money to add to the Library to which, it is evident, they attached great importance. In addition to the 500 dollars given to Doctor Brown for the purchase of medical books, 600 dollars

was appropriated for the purchase of law books. Thus, was the beginning of Transylvania Medical Department and the Transylvania Medical Library.

Doctors Brown and Ridgely taught such students as came to them but no attempt was made to build a medical school building and conduct classes which would lead to degrees in medicine until the school was reorganized. When this was done, in 1815, Dr. Benjamin Winslow Dudley was appointed Professor of Anatomy and Surgery, and a number of other distinguished physicians were appointed to its faculty, and it became one of the best known medical colleges in the United States.

The first graduating class of the reorganized school was in 1818, and the first graduate was John Lawson McCullough, who received his A. B. degree, in 1809, from the College of Liberal Arts of Transylvania University, and his M. D. degree, in 1818, from the Medical College.



FIG. 1.—First building of Transylvania Medical Department. Built in 1827 and taken over by the City of Lexington in 1839 and the rear part of it burned in 1854. The front part is still standing.

In 1820, the sum of \$17,000.00 was furnished to Dr. Charles Caldwell, with which to purchase books in Paris for the Medical Library. This money was raised from the City of Lexington and the Kentucky Legislature and from private sources, and was given to Dr. Caldwell personally.

He writes in his autobiography: "The time of my arrival in Paris was uncommonly and unexpected propitious for my purpose. The ravages and waste-laying of the French Revolution had not entirely passed away. Toward the close of the catastrophe the libraries of many wealthy and literary persons had found their way to the shelves of the book seller. No sooner was I apprised

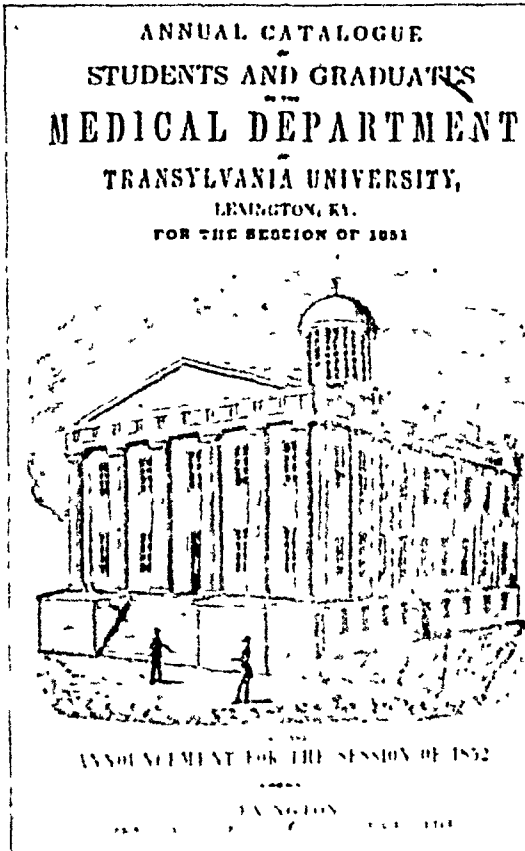
of these precious repositories than I procured permission to ascertain of what they consisted. Some of them were stored with venerable literature. I found, and purchased at reduced prices, no inconsiderable number of the chemists and the choicest works of the Fathers of Medicine from Hippocrates to the revival of letters. Works which in no other way, and perhaps at no other time could have been collected so readily and certainly on terms so favorable in either Paris or any other city in the world."

Again, in 1839, Dr. Robert Peter and Dr. J. M. Bush spent \$11,000.00 in London and Paris for books and apparatus for the Medical College. These trips by Doctors Caldwell, Peter and Bush procured for the University about 10,000 valuable medical books and also specimens and apparatus for teaching and various plates and pictures and several microscopes and a camera made by Louis J. M. Daguerre. He was a French painter and inventor of the Daguerre pro-

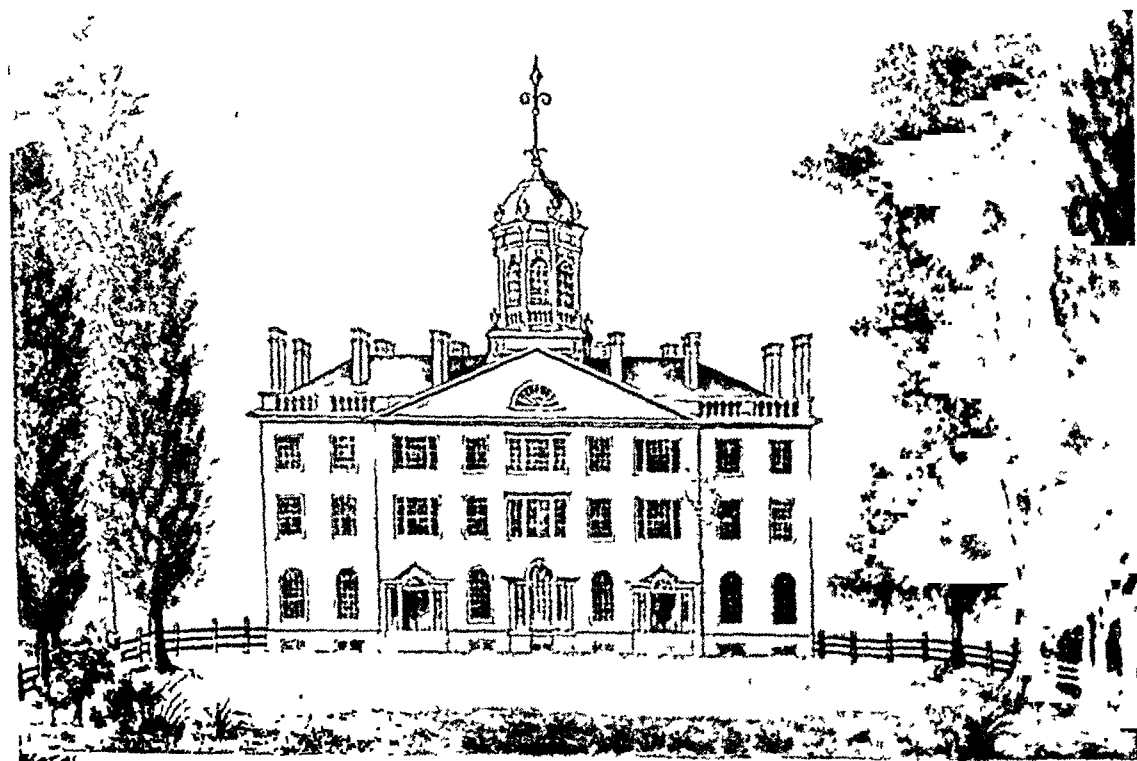
FIG. 2.—Second Medical Building built in 1839 and burned in 1865 while being used as a Government Hospital by the United States Army troops.

cess method of obtaining pictures by the action of sunlight. His perfected process was communicated to the Academy of Sciences on January 9, 1839. According to reports in the Transylvania Library the Daguerre camera was first used in New York, August, 1839, and they were using it at Transylvania University in Lexington in October, 1839. The original bills and expense accounts of these two trips to Europe by Doctors Caldwell, Peter and Bush are on file in the Library.

Dr. Thomas D. Mitchell said, in his valedictory to the graduating class in 1839-40, in addition to describing lecture halls and courses of instruction and



interesting cases shown and operated upon: "A well-lighted library apartment 30 x 60 feet and 15 feet in height, with the richest collection of splendid and rare plates, standard medical works in the living and dead languages, European or American periodicals that can be found in any similar institution in the



THE PRINCIPAL BUILDING OF TRANSYLVANIA UNIVERSITY, INSCRIBED TO  
PRESIDENT HOLLEY.

FIG 3.—Main Building Transylvania University built in 1818 and burned in 1829.



FIG. 4.—Morrison College built in 1833 by Gideon Shryock and is still standing.

country, will attract your notice. Arranged according to their various affinities, not less than 7,000 volumes will be found in this department; and these culled from the best and most ample sources, so as not to leave a single chasm, that may not be filled up by its annual income. In this, and the contiguous rooms, the most accurate and delicate paintings of medicinal plants the Capitol of France could furnish, will also find a conspicuous place. I need not tell you that these exquisite paintings are true to life, for you have already satisfied

yourselves that such is the fact. In all, there are 51 of these drawn and painted after the living specimens in the Jardin des Plantes, by the ablest Parisian artists.

They are the only collection of the kind in the country. In near association will be seen the drawings and paintings for the surgical, medical, obstetrical and chemical departments, designed to facilitate the studies of the pupil and well-adapted for the illustrations of the several teachers. Twenty-eight of the most accurate pictures representative of morbid structure, made by the ingen-



FIG. 5.—Dr. Samuel Brown

uous Thibert, whose efforts have received the highest praise from the prince of pathologic anatomists Cruvalhier, are already in our possession.

These, as you know, exhibit, most accurately, the various changes induced by disease in the most important organs, and greatly aid the professor of Theory and Practice in the prosecution of his duties. But these are only the beginning of our means in this department, since, at least, two of one are in possession of the process as well as the test for extending the number, so as to embrace every shade of morbid anatomy, that may be available in teaching practical medicine. The fair and variegated models in wax of the disease of the genital organs and especially of the female, whose excellence could not be

fully set forth without trespassing greatly on your patience, are all regarded as of inestimable value; and having been procured exclusively from a private cabinet are without a parallel either in this country or any other. Already, you have admired a few of the beautiful preparations, attended to and recently displayed, as well as our present means would allow. But arranged as the whole will be in the new museum.

With the most favorable light for this fine exhibition you will behold a collection far in advance of any in the great West, and excelled by none save that of the present school in Philadelphia. In close proximity to this is, as well as to the ampitheater, will be found the spacious dissecting room furnished with every appendage that can give interest or value to that department. The gallery of chemical and philosophic apparatus so arranged as to be in view of the class while seated in the hall or so inaccessible as to be more minutely inspected at leisure will claim a special notice. Its large model steam engine; its apparatus for solidifying carbonic acid gas; its multiplied and greatly diversified electrical, galvanic and magnetic arrangement; its splendid air pumps; its mounted concave mirrors; its compact and highly finished locomotive, with a hundred other beautiful works of the first artists in Europe or America—all calculated to augment the facilities of chemical instruction, together with mineralogic and geologic cabinets, will convince the most skeptical that nothing is wanting to make up the full inventory of a perfect medical college."



FIG. 6.—Dr. Charles Caldwell.

From 1819–1826 the distinguished Botanist, C. A. Rafinesque, was professor of Natural History at Transylvania University, and for part of that time was Librarian. Mrs. Charles F. Norton says: "It is probably owing to his influence that the library is so especially rich in works of Botany and Natural History."

It is impossible to go into details as to the books contained in the fine old collection, but as a result of the enthusiasm and generosity of those who have had charge of its destinies in the early years it became a most valuable adjunct to the work of the institution, and remains to this day one of the most notable collections of its kind in the country. And many authorities and investigators have visited there and used the Library in their research.

When Albert H. Buck, who was Professor of Diseases of the Ear at Columbia University, was writing his work on "The Dawn of Medicine" this book being a continuation of his former book "The Growth of Medicine," he had failed to find trustworthy information on his first visit to Europe and on

another trip he could not find what he wished and he was disposed to abandon the undertaking. This news item was published in a scientific journal and Mrs. Charles F. Norton, the Librarian of Transylvania College saw it and wrote him that he might find his information in the Transylvania Library. He rather doubted her statements but he wrote her that he would submit a list of 25 books he needed to see if she had any of them and she found 23 out of the 25. She then sent him another list of 100 French, English and Latin books and wrote him that Transylvania University would be glad to allow him to use the material in the Library. He then came to Lexington and stayed seven months, most of the time in the Transylvania University Library, and finished his book.

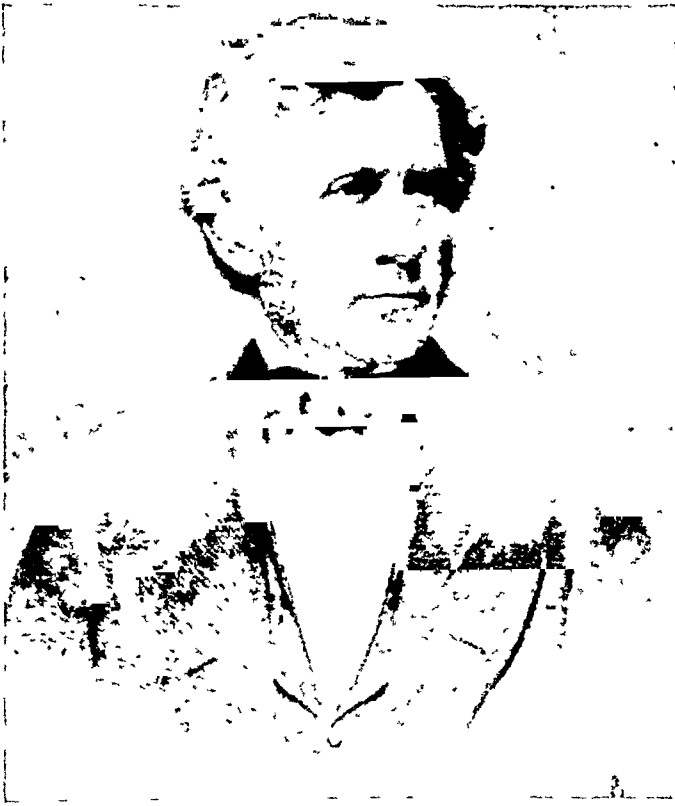


FIG. 7.—Dr. Daniel Drake.

A most interesting feature in the old catalogues and lists of pupils, is that after the pupil's name and address is the name of the physician who was his teacher or preceptor.

Each graduate wrote an Inaugural Dissertation, or Thesis on his graduation. All of these are bound in volumes and are kept in the Library, and there are 1,860 of them on file, and they are most interesting and a great many have been consulted by students of medical history and descendants of the writers.

In 1827, professors and citizens of Lexington formed a joint stock company, whereby they raised enough money to erect a Medical Hall, which was used until 1839, when the City of Lexington built a new hall for the Medical School, taking one old hall over for municipal purposes. The second Medical Hall was destroyed by fire during the Civil War in 1865, after it had been taken over by the United States Government as a hospital.

The Medical School continued to grow and flourish, and Dr. Thomas D. Mitchell said about it the following: "That for its vigorous prosperity and the rapid increase of its classes the Medical School of Transylvania is without a parallel, certainly, in the United States there is nothing comparable to it. This is the highest eulogy the institution can receive. The most eloquent and forcible language in praise of it would be spiritless and feeble contrasted with the power of the foregoing figures."

In the years, from 1815-1859, when the last class was graduated, they had 6,456 students and graduated 1,881 Doctors of Medicine, and in the last page of the Trustees' Book, of that year, are listed the names of the students and graduating class, and signed by Robert Peter, Dean, who wrote after his signature: "And so ended the first cycle of the Medical Department of Transylvania University."

R. T. Durrett, President of the Filson Club, of Louisville, wrote the introduction for the preface on the "History of the Medical Department of Transylvania University," by Dr. Robert Peter, and closed with the following:

"There is in our nature something like the love of the relic which makes us revere the memory of Transylvania University. Early in the year 1799 a Medical Department was attached to this University, which was the first Medical College in the great Mississippi Valley and the second in the whole United States. The Medical Department of the University of Pennsylvania antedated it, as it antedated all others afterward established in any part of our vast domain. We can not, like our English cousins, go back along the pathway of centuries to the colleges of Oxford and Cambridge, and revere them for their age; We have nothing in our country that partakes of such age. We are a young people in a young country, and our Transylvania Medical College was old enough, from our standpoint, to be crowned with hoary years. We revere it as the first Medical College on this side of the Alleghanies. We revere it for the efforts it made to prepare our young physicians to cope with the diseases that afflicted our people. We revere it for the good name it gave our State in the fame it acquired. We revere it for the success of Professor Brown in introducing vaccination in advance of its discoverer, for the brilliant and numerous operations in lithotomy by Professor Dudley, and for the noble efforts of others of its professors in prolonging human life and mitigating its pains. What it did in the day of its glory is written in its annals and he who considers them



FIG. 8.—Dr. Benjamin Winslow Dudley—From Jouett portrait hanging in Morrison College Chapel.



seriously will hardly doubt that the Medical College of Transylvania University is worthy of its record."

It would be appropriate to mention here that Colonel Durrett, whose statement I have just read, was not entirely familiar with the facts about the first Medical Schools. According to the best information I can obtain the first Medical School in the colonies was that of Philadelphia, founded in 1765; then followed Kings College in New York, 1767, and Harvard Medical School, Boston, 1783; Dartmouth at Hanover, New Hampshire, 1798, and Transylvania Medical College organized in 1798, and started in 1799, but was reorganized, as I have stated, in 1815, and graduated its first class in 1818, and continued until 1859.

Frederick Ridgely (1757-1824) was a native of Elk Ridge, Anne Arundel County, Maryland. He had begun the study of medicine when the Revolution began, and he at once joined a corps of riflemen from Virginia and Maryland

as a surgeon. He served in the army throughout the war with the exception of two brief periods, one of which he devoted to medical study in Philadelphia, and during the other he served as surgeon to a privateer which was captured by the British in Chesapeake Bay, Ridgely escaping by jumping overboard and swimming ashore. After the war he practiced for a time in Maryland, and then moved to Lexington, Kentucky. In 1799, he was appointed professor of Materia Medica, Midwifery, and Physics in Transylvania University.

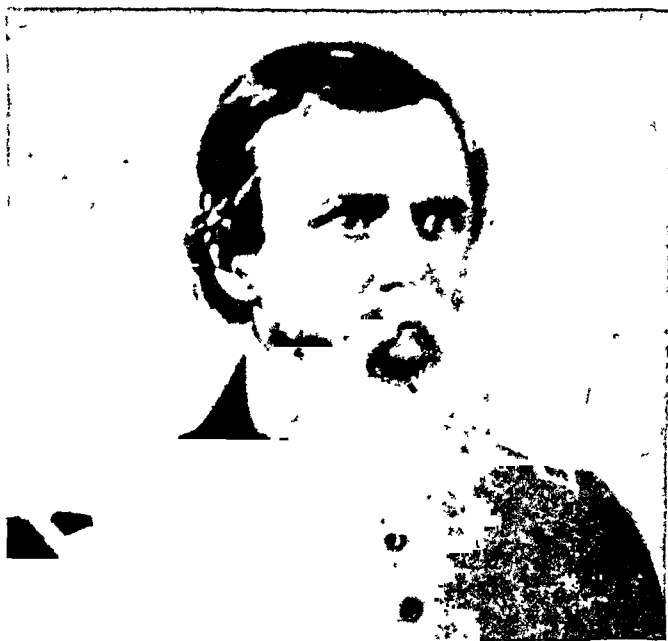


FIG. 9.—Dr. Ethelbert Ludlow Dudley.

He was an excellent teacher and, in 1799-1800, he delivered to the small class of medical students, then in attendance, a course in Public Instruction, and he continued to do that for a number of years, and, in addition, he had many office pupils, among them being Dr. B. W. Dudley and Walter Brashear. Dr. Dudley always spoke with warmth and esteem of his scholarly and urbane preceptor as a physician whose high culture of mind and educated moral tone reflected dignity upon his profession.

Although Walter Brashear (1776-1860) was never a teacher nor a writer, he deserves mention in this association as one of the men who shed luster on surgery in Lexington, Kentucky. In 1806, while practicing at Bardstown, Kentucky, he amputated successfully through the hip joint, 16 years before the same operation was performed by Valentine Mott.

Samuel Brown (1769-1830) was a native of Virginia. His father, a Presbyterian clergyman, sent him to Dickinson College, at Carlisle, Pennsylvania.



FIG. 10.—Dr. Robert Peter, age 34.  
Miniature painted by Chazal in Paris  
in 1839.

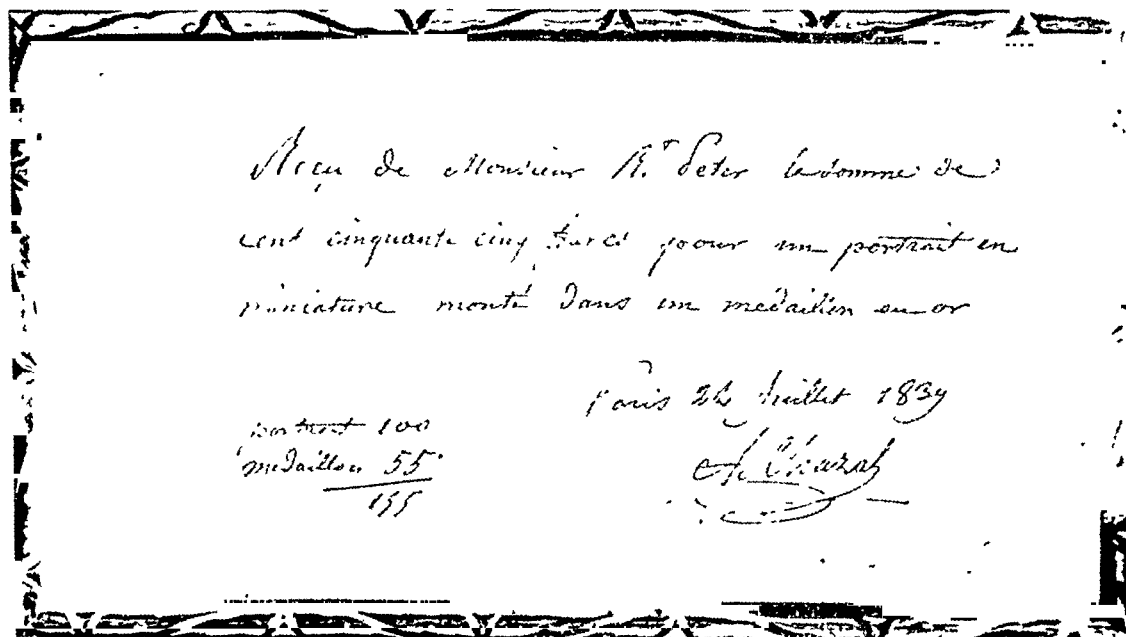


FIG. 11.—Receipt for miniature and medallion.

After receiving his A. B. degree from that institution, he studied medicine first with his brother-in-law, Dr. Humphreys at Staunton, Virginia, and then

as a private pupil under Dr. Benjamin Rush, in Philadelphia. He then went to Edinburgh but returned to the United States without having taken a degree. In 1797, he settled at Lexington, Kentucky, and two years later was appointed as Professor of Chemistry, Anatomy and Surgery at Transylvania University. As early as 1802 he had vaccinated more than 500 persons for the prevention of smallpox, when in New York and Philadelphia, physicians were just making their first experimental attempts. The virus he used was taken from its original source, vesicles from the cow, and was used in Lexington even before Edward Jenner could gain the confidence of the people of his own country, England. As is well known, Jenner was ridiculed and persecuted, and it took him a good many years to convince the people and physicians about the truth of his reasoning and discoveries; Doctor Brown, however, accepted his reasoning and used vaccination early and as often as was necessary.

A curious anecdote was told of Dr. Samuel Brown by his nephew, the late Orlando Brown, of Frankfort, in a letter to Doctor Peter: "I remember once when talking of calomel, he, Doctor Brown, said he never would forget the first dose of it he gave a patient. It was looked upon as "The Hercules," and he used it accordingly. The case was desperate and he resolved to venture upon calomel and give a strong dose. He, accordingly, weighed out with scrupulous accuracy four grains, gave it to his patient, and sat up all night to watch its effects. The man got well and then Doctor Brown afterwards used calomel more freely. What would he have thought of the heaping tablespoonful doses frequently repeated *pro re nata*, or the pound of calomel taken in a day and the patient surviving, which characterized the cholera treatment of one of the later professors of Transylvania Medical School.

In 1802, Samuel Brown founded the famous Kappa Lambda Society of Aesculapius, a secret organization of medical students and physicians of which chapters were organized throughout the United States. The purpose of the Society was to elevate the standards of the profession and do everything honorable to promote the welfare of physicians in and out of the Society, and to abide implicitly by a stringent code of ethics that had been prepared for the guidance of the members in their intercourse with each other, and with society at large, and to promote the advancement of medical knowledge, but, unfortunately, quarrels and dissension among its members finally caused its dissolution. In 1826, the Society founded the North American Medical and Surgical Journal at Philadelphia, Pennsylvania with a most respectable body of editors—Dr. Hugh L. Hodge, Dr. Franklin Boche, Dr. Charles S. Meigs, Dr. B. H. Coates and Dr. Rene de la Roche. Shortly afterwards both in Philadelphia and New York City quarrels between doctors demonstrated the powerful influence which Kappa Lambda was exerting in medical matters. As a result the Society fell into disrepute and the Journal and Society itself passed out of existence in 1852. Dr. B. W. Dudley was listed as one of the members of the Kappa Lambda Society in 1803, before he went to the University of Pennsylvania Medical College in 1804. Dr. Chauncey D. Leake has published a most interesting history of the whole affair—"What was Kappa Lambda?"

Of all the Professors of the Medical Department Dr. B. W. Dudley stands

out as the most prominent. He was born in Spottsylvania County, Virginia, and his family moved to Lexington, Kentucky when he was very young. He began the study of medicine under Dr. Frederick Ridgely (1757-1854), who with Dr. Samuel Brown constituted the first medical faculty of Transylvania University. In 1804, Dudley entered the Medical School of the University of Pennsylvania from which he received the degree of M. D. While in Philadelphia he had as fellow students Daniel Drake, John Esten Cooke and William H. Richardson with all of whom he was closely associated in later years. In 1810, Dudley went abroad and passed four years in study under the leading men in France and England. He regarded Abernathy as the greatest of surgeons but Sir Astley Cooper as the most skillful and graceful of operators. While abroad he became a member of the Royal College of Surgeons, and it has been reported that Napoleon offered him the place held by Baron Larrey as his Surgeon in Chief. From 1815-1850, when he retired from the Medical Department of Transylvania University, Dudley taught Surgery and Anatomy, although, in 1844, he gave up the chair of Anatomy and continued as Professor of Surgery.

Dudley was especially renowned for his skill as a lithotomist. Stone in the bladder seemed to have been unusually prevalent in Kentucky in those days. Dudley used the lateral method and employed the gorget devised by Cline. He, thus, cut 225 persons for stones and only lost six of his cases.

Dudley was wont to attribute his success, in great part, to the great care which he took in preparing his patients for operation. He laid great importance on the use of boiled water in operations. Dudley successfully ligated the subclavian artery for axillary aneurysm. In 1828, he published a report of successful cases in which he had trephined the skull for the relief of epilepsy due to pressure on the brain. Henderson says he is probably the first surgeon in the United States to perform this operation. He was an admirable teacher and dominated the affairs of the Medical School at Transylvania. He amassed a very considerable fortune, and he was very generous in his charitable contributions, and also to his students who needed help. After retiring Dudley lived in his country house "Fairlawn" near Lexington, where he succumbed to a stroke of apoplexy in his 85th year. Dr. Samuel D. Gross did not profess the same admiration of Dudley as did most of his contemporaries. He visited Lexington to see his work in 1841, and writes: "At the same time to which I refer he was at the height of his reputation as a surgeon. Dudley's lecture on the day of my visit was on the Anatomy of the Muscles of the Forearm, and a more puerile discourse I have never listened to. It would hardly have been creditable to a tyro in anatomy. Dudley was well skilled in the use of the knife, was an excellent mechanical surgeon, or in other words an operator. Of surgical pathology he knew little or nothing: Certainly his teaching was far in arrears of the existing state of the Science.

His lectures on surgery, however, were always interesting, from the fact that they abounded in practical matter, the result of wide and ripe experience. His forte was lithotomy, in which he was for a long time *facile princeps*. It is said that he performed lithotomy 225 times, with the loss of only six or seven

cases. I have never, however, given credence to this statement because it was not verified by statistics. Dudley kept no record of his cases, of their sex, age, residence or of their condition before or after the operation. As most of his patients came from a distance, the men all lodged in one building, which was in charge of an ignorant steward. This man acted as nurse and when interrogated about the number of cases operated upon in any given time he helplessly raked his brain for an answer. Dudley did some good work in the ligation of arteries, chiefly limited, however, to those of the neck, and he may be regarded as the pioneer for the cure of epilepsy dependent upon injury of the skull, in which his success was remarkable. Dudley was one of those men who never



FIG. 12.—Dr. Robert Peter as an elderly man.



FIG. 13.—Portrait of Constantine A. Rafinesque.

correct the deficiencies of their early education. His style as a writer was execrable and his thoughts were clothed in ungrammatical English. Some of his letters would have disgraced a school boy."

Many interesting stories have been told about Dudley. He was worshiped by his students and beloved by his patients and the townspeople of Lexington, but, at times, there was great dissension among the members of the faculty and Dudley seems to have had his share of the quarrels and bickerings among them. One of his collateral descendants has told me that the family have always understood that he was a very kind hearted man and that he would do anything for his friends, and patients, and family, but that he was red-headed, and very impulsive and explosive when he was questioned or became irritated. One of the most interesting of the stories about him was that of the duel between him and Richardson. Dr. C. C. Graham, in his letters to Dr. Robert Peter, writes very vividly about it. He says that two drunken Irishmen had a "knock-down and drag-out fight, and one fell and struck the back of his head against the curbstone and later died of concussion of the brain, and Dudley and Drake were summoned by the coroner to examine the case and testify before the jury.

Drake refused to attend but Dudley did testify and gave his opinion. Afterwards, Drake insinuated that the circumstances did not justify Dudley's decision. Before this Dudley and Drake had had disagreements and quarrels and Drake had written several pamphlets appealing to the "Justice of the Intelligent and Respectable People of Lexington." Dudley had answered them and charged that he, Drake, had attempted to destroy the Medical College of Transylvania while he was a professor in the institution. The appeals of Drake and Dudley's accusations and answers to Drake were published in pamphlet form and some of these pamphlets can be seen now. They are very interesting. In Drake's second appeal he said, in the language of Dean Swift, I may exclaim: "Strange such a difference should be, Twixt tweedle-dum and tweedle-dee."

It seemed that he, Drake, was getting the better of the controversy, so Dudley sought satisfaction by challenging Drake to a duel. Drake declined but Richardson, as his friend, accepted Dudley's challenge. Doctor Graham in his letters described the very serious preparation by Dudley for the duel, and how Dudley brushed up on his marksmanship with a pistol for several weeks before the duel and at the time of it he wore a green great coat which he had purchased in Paris. This coat had large bright buttons on it and Graham cut these buttons off before he and Dudley went to the duel. In the duel Dudley's shot injured Richardson's "inguinal artery" and he would have bled to death but for Dudley's aid, who knowing where the artery passed over the ilium checked the blood with the pressure of his thumb while Richardson's surgeon ligated the vessel. After this duel Dudley and Richardson became very great friends.

From all of the literature and stories about Dr. Dudley he certainly must have been a great man and a great surgeon, although, he had his faults such as many of the other great men.

James Mills Bush (May, 1808-February 14, 1875) studied medicine first with Dr. Alben Goldsmith at Louisville, then, with Dr. B. W. Dudley, while taking the regular course at Transylvania University Medical College, from which he received his M. D. degree in 1833. In 1837, he was appointed Adjutant Professor in Anatomy, and, in 1844, full Professor of Anatomy in his alma mater, Dudley resigning the chair of Anatomy in his favor. In 1850, he



FIG. 14.—William A. Cowper—Anatomy of Humane Bodies. Published 1698.

moved to Louisville and was appointed Professor of Surgical Anatomy and Operative Surgery in the Kentucky School of Medicine which had just been established, and he lived there for a time. Bush and Dudley formed a partnership in their practice which was most successful. Dr. Bush was particularly expert with the lithotrite, and he is said to have performed 210 litholapaxys with but four deaths. Bush had arranged with a Mrs. Bentley to lodge his patients and to aid him in their care. They frequently came from a considerable distance. He later was active in establishing St. Joseph's Hospital, at Lexington, Kentucky, which was the first hospital in Central Kentucky.

Charles Caldwell (May 14, 1772-July 9, 1853) was a native of North Carolina. After teaching school for some years he graduated in medicine from the University of Pennsylvania. His career as a student was stormy and marked

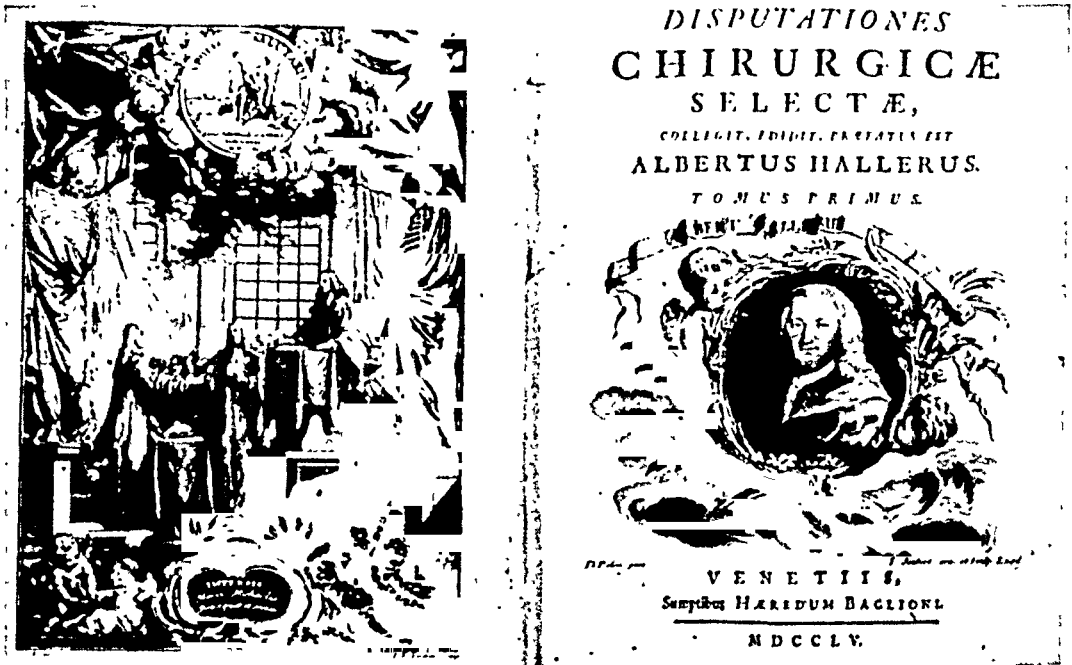


FIG. 15.—Albert Haller—*Disputationes Chirurgicae Selectae*. Published 1755.

by his aggressiveness and many quarrels with his associates. At first an ardent admirer of Benjamin Rush, he ended by quarrelling with him and daring to openly speak against his well known views on yellow fever. The young student wrote much for the newspapers and delighted in the notoriety he achieved. He embraced every opportunity to place himself in the limelight. In his autobiography he describes with magnificent conceit his services as surgeon with the troops who were sent to put down the Whiskey Insurrection. He seems not only from his own account, but from the statements of others, to have labored bravely in the yellow fever hospitals during the epidemic from 1793 around devastated Philadelphia until 1805. He sought in vain to get a professorship in the University of Pennsylvania. He organized classes for private teaching on several occasions but his efforts all ended in failure, and he was involved in one quarrel after another with his fellow physicians. He wrote many papers for medical journals. He at one time edited "The Portfolio" and

This was opposed by Dudley, and other members of the faculty, and the trustees of Transylvania formally dismissed him from the faculty. He went at once to Louisville and enlisted the interest of the citizens, so that \$20,000 was soon raised for the establishment of the Louisville Medical Institute. Caldwell was appointed Professor of the Institutes of Medicine, Medical Jurisprudence and Clinical Medicine. In 1846, the Louisville Medical Institute became a part of the University of Louisville. His writings and speeches both in Pennsylvania and Kentucky were most voluminous. While in Pennsylvania he edited Cullens Practice of Physic, and delivered many clinical lectures in Old Blockley Hospital in Philadelphia, and, in 1819, even wrote the Life and Campaigns of General Green. One of his most erudite articles is on Phrenology. He was a friend and physician of Henry Clay, who, in one of his speeches in the United States Senate, said of him: "A new philosophy has sprung up within a few years past called phrenology. There is, I believe, something in it, but not quite as much as its ardent followers proclaim. According to its doctrines, the leading passions, propensities, and characteristics of

He continued teaching medicine and clinical practice until 1849, when he had another of his misunderstandings and quarrels and was dismissed from the



FIG. 16.—*Aur. Philip Theoph. Paracelsi—Opera Omnia. Published 1658.*



Dr. David W. Yandell in his Doctor's Address on the occasion of the Semi-Centennial Anniversary of the Medical Department of the University of Louisville, 1887, said: "The central figure of that group of noted teachers who founded the University was Charles Caldwell. He was a massive man in body and in mind. He was both tall and broad. His carriage was erect. His head was simply grand; his mouth was large; his eyes were bluish-gray. He had studied



elocution. His gestures and his speech were studied also. His manners, usually cold, were always stately. He spoke in long, well-rounded periods, and in a great sonorous voice. He was learned in the languages, fond of study, and of abstemious habits. Besides all this, he was a man of affairs, and delighted in controversy. He taught the physiology of his day, which was then largely the physiology of the ancients, but he taught it in so impressive a manner that his classes received it as gospel and voted him its greatest expounder."

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moved to Transylvania Medical School as Professor of Materia Medica and Medical Botany, but returned to Cincinnati, and, in 1818, founded the Medical College of Ohio. After a controversy in Cincinnati, he returned to Lexington in 1823 and stayed until 1827, being the Dean of the Faculty. He declined a chair at the University of Virginia in 1830, but he accepted one at the Jefferson Medical College, Philadelphia, the same year, and again came back to the Medical College of Ohio in 1830-32. He founded a new school as a department of Cincinnati College and taught in it 1835-1839, and he afterwards accepted a chair in the Louisville Medical Institute 1838-1849, and then went back to Cincinnati as a member of the faculty of the Medical College in 1849-50. In 1827 he was editor of the Western Medical and Physical Journal, but his



THEOPHILUS BONETI

THEOPHILI  
**BONETI**  
MEDICINÆ DOCTORIS.  
**SEPULCHRETUM**  
SIVE  
**ANATOMIA PRACTICA.**

CADAVERRIBUS MORBO DENATIS.

*Præparata*  
**HISTORIAS ET OBSERVATIONES**

*(Cum Illustratione Anatomica, quæ præcipue Cadaveribus, et aliis  
Quædam præparata sunt, quæ non solum in Anatomia, sed et in  
Medicina, et Veterina, et Nova, et Præparata, et aliis.)*

*Cum Illustratione Anatomica*  
**EDITIO ALTERA, QUAM NOVIS COMMENTARIIS**

*et Observationibus, quæ præcipue Cadaveribus, et aliis  
Quædam præparata sunt, quæ non solum in Anatomia, sed et in  
Medicina, et Veterina, et Nova, et Præparata, et aliis.)*

**JOHANNES JALOUSUS HINGETUS, MEDICINÆ DOCTOR,**

*et Illustratione Anatomica, quæ præcipue Cadaveribus, et aliis  
Quædam præparata sunt, quæ non solum in Anatomia, sed et in  
Medicina, et Veterina, et Nova, et Præparata, et aliis.)*

**TOMUS PRIMUS**



**LUGDUNI**  
Sumptibus **CRAMER & PERACHON.**  
**M DCC**

FIG. 18.—Theophilus Boneti—Sepulchretum. Published 1700.

chief work is his "Treatise on the Principal Diseases of the Interior Valley of America," published in 1850. He died in Cincinnati, November 5, 1852, age 67, literally worn out by his work.

Dr. David W. Yandell says: "As a lecturer Doctor Drake had few equals. He was never dull. His was an alert and masculine mind. His words are full of vitality. His manner was earnest and impressive. His eloquence was fervid." Soon after Dr. Yandell had entered the practice of medicine Drake had told him: "I have never seen a great and permanent practice the foundations of which were not laid in the hearts of the poor. Therefore, cultivate the poor. If you need another, though sordid reason, the poor of today are the rich of tomorrow, in this country. The poor will be the most grateful of all your patients. Lend a willing ear to all their calls."

Dr. S. D. Gross says of him: "He was a self-made man, he possessed genius of a superior order and successfully coped with his colleagues for the highest place in the school (Transylvania). Of all the medical teachers I have ever known, he was, all things considered, one of the most able, captivating and impressive. There was an earnestness, a fiery zeal about him in the lecture room which encircled him, as it were, with a halo of glory."

Dr. Ransohoff says: "It would be beyond reason on an occasion like this to touch upon every activity of so versatile a man as Drake, and one can only touch upon the chief of the many radiating ways travelled by the influence of this master mind. And of them, next to that of his written work, was that of the lecture room. Drake loved to teach, and because he loved it, did it well. During 35 years, he held nine professorships, in five different schools. A restlessness innate in his make-up and an habitual discontent with his professional environment made him an itinerant in medicine. The longest continuous professorship, ten years, he held in Louisville."

Dr. James Overton was appointed to the chair of Materia Medica and Medical Botany in 1809. When the faculty was reorganized in 1815, he was appointed to the chair of Theory and Practice. He moved from Lexington to Nashville, Tennessee, in 1818, where he practiced his profession for many years, dying at an advanced age. While in Nashville he became the physician and intimate friend of Andrew Jackson and was often entertained at the Hermitage.

John Esten Cooke was a native of Boston, his parents being from Virginia. He succeeded Daniel Drake as Professor of Theory and Practice at the Transylvania Medical College in 1824, and continued until 1837, when he moved to Louisville. He was greatly beloved by his patients and fellow physicians and Dr. Lunsford P. Yandell, Sr., wrote about him. "that Dr. Cooke was one of the few men who might have been trusted to write his own autobiography. He would have reviewed his career with a truthfulness, a modesty, a candor that would have exalted his character in the eyes of men. His works will be read by the curious for a long time to come, and will always be read with advantage by the earnest student." He was a great believer in medicine and his chief reliance was placed on calomel and quinine and his enormous doses of them created many arguments among his colleagues. A great many stories have been told about Dr. Cooke.

Dr. Lunsford P. Yandell, Sr., was called to the chair of Chemistry and Pharmacy in the Medical Department of Transylvania University, March 16, 1831. He occupied various chairs in the Medical School until he resigned in 1859 to accept a chair in the Medical School of Memphis, Tennessee. During the Civil War he devoted himself to hospital service. In 1862, he was licensed to preach by the Presbytery of Memphis, and, in 1864, was ordained pastor of the Dancyville Presbyterian Church. In 1867, he resigned his pastorate and returned to Louisville to resume the practice of medicine. While in Lexington he was for some years editor of the Transylvania Journal of Medicine, and in Louisville, he was editor for the Western Journal of Medicine and Surgery. He was the author of many medical papers and addresses. In 1872, he was elected President of the College of Physicians and Surgeons of Louisville, and

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at the time of his death he was President of the State Medical Society of Kentucky. His death occurred February 4, 1878.

Charles Wilkins Short was another of the professors at Transylvania. He was born in Woodford County, Kentucky and was a most zealous and industrious botanist. He had an extensive herbarium and exchanged specimens of his with various botanists of the world. At his death his vast collection of botanical specimens to which he had devoted so great a portion of his life, was bequeathed to the Smithsonian Institute at Washington, but as there was no appropriate place there in which to display so large a collection, it was given to the Academy of Natural Sciences at Philadelphia. He was Dean of the Medical Faculty of Transylvania for about ten years.



FIG. 19.—William Fabricius—Opera. Published 1646.



FIG. 20.—Ambroise Pare—Les Oeuvres. Published 1607.

Ethelbert Ludlow Dudley was a nephew of the distinguished physician, Dr. B. W. Dudley, and was his private pupil and assisted him for many years. He graduated at the Medical Department of Transylvania University in 1842, and he was appointed Demonstrator of Anatomy in Transylvania. He afterwards served as professor of General and Pathological Anatomy and Physiology, and he was editor of the Transylvania Medical Journal and, in 1858, visited Europe for professional improvement, and he later taught Anatomy and Histology in the Kentucky School of Medicine in Louisville. When his uncle, Dr. B. W. Dudley, retired from Transylvania, he was appointed Professor of

Surgery in Transylvania, and after that he taught surgery in the Kentucky School of Medicine and gave clinical instruction in the Marine Hospital in Louisville. After that he resigned his position in Louisville and returned permanently to Lexington and resumed his practice there. At the outbreak of the Civil War he volunteered and organized a regiment for active service instead of taking the position of Medical Director which had been offered him. He was physician and surgeon to his men as well as their Commanding Officer, and while on an expedition in Southern Kentucky contracted typhoid fever and died February 20, 1862.

It is told by a member of his family that when he was a very young graduate of medicine he was assisting his uncle, Dr. B. W. Dudley, in an operation for stone in the bladder. Dr. Dudley was seized with a violent sick headache and became dizzy, being subject to these migraine headaches. He was unable to proceed so asked Dr. Ethelbert Dudley to go on with the operation. With much trepidation he did this successfully and the patient survived. This was his first lithotomy.

A great many of his papers and personal case notes were in the possession of his grandson, the late Dr. Scott Dudley Breckinridge, of Lexington, and were destroyed in a fire at his home several years before Doctor Breckenridge's death.

Dr. William H. Richardson was appointed professor of obstetrics, when the faculty was reorganized in 1815, and taught until the time of his death in 1844. Dr. Richardson was highly respected by his pupils as a practical teacher, notwithstanding the fact that he had not had the advantage of a college education. He was a man of great energy and of many admirable traits of character. His pupil, the late Dr. Lewis Rogers, in his address as President of the Kentucky State Medical Society, in 1873, speaks about him as follows:

"Few men ever had nobler traits of character. He was warm-hearted, brave, and a sincere friend. I knew him from my earliest boyhood, and have passed away many happy and instructive hours at his magnificent home in Fayette County. His hospitality was profuse and elegant. I listened to his public teachings as a professor with interest and care, because I knew he taught the truth as far as he possessed it. He was not scholarly nor graceful and was not fluent as a lecturer, but he was ardent and impressive, sufficiently learned in his special branch and had at his command a large stock of ripe experience. I honor his memory beyond most men I have known."

Dr. Robert Peter was born in England, January 21, 1805. His parents settled in Pennsylvania and he attended the Rensselaer Institute Scientific School at Troy, New York, where he lectured on the Natural Sciences, and he taught Chemistry and the Natural Sciences in several schools in Pennsylvania. In 1832 he came to Lexington, Kentucky, to deliver a course of lectures at the Eclectic Institute in Lexington, and, in 1833, he was elected to the Chair of Chemistry in Morrison College, Transylvania University. Besides teaching chemistry he studied medicine at Transylvania University, and received his diploma in 1834. In 1838, he was elected to the Chair of Chemistry and Pharmacy at Transylvania Medical Department. From 1847-1859 he was Dean

of the Faculty and Librarian as well. In 1839, he with Dr. James M. Bush made a trip to London and Paris for the purchase of books, apparatus, and other means of instruction for the Medical Department.

He wrote from London, August 11, 1839: "We have bought a great many fine books and a great deal of excellent apparatus and anatomical and other models. Transylvania will shine. No other institution in any part of the world will be able to compare with her in the means of instruction. In fact, I have seen none in Europe that is more completely prepared to teach modern medicine." He gave his attention to Chemistry, Geology, Mineralogy, Zoology and Botany. He was associated with Dr. Charles W. Short in the last named (Botany). He was the author of the first Geological survey of Kentucky, which was begun in 1864. He continued to teach and write and lecture and retained an activity of mind up to a very short time before his death which took place at Winton, eight miles from Lexington, at the age of 89, April 26, 1894.

The arrangement of the Medical Library is still as it was a century ago. The old classification is as follows:

- A. *Practical Medicine*, including Pathology and Mineral Springs, etc.
- B. *Anatomy and Surgery*, including Morbid Anatomy and Dentistry.
- C. *Physiology*, including Medical Jurisprudence, Phrenology and Hygiene.
- D. *Obstetrics*, including Diseases of Women and Children.
- E. *Chemistry*, including Electricity, Magnetism.
- F. *Materia Medica*, including Pharmacy, Medical Botany, and Dietetics.
- G. *Natural History*, including Geology, Mineralogy, Botany, Zoology, Comparative Anatomy and Physics.
- H. *Scientific Periodicals*.
- I. *Periodical Medicine*.
- K. *Miscellanies*, including Physics (or Natural Philosophy), Voyages and Travels, Biography, Veterinary Medicine, Meteorology, Agriculture, Horticulture, Arts and Trades, Statistics and Works on General Literature.
- L. *Encyclopedias*, including Transactions of Societies, the Works of the Old Fathers of Medicine and the Theses.

#### *Practical Medicine:*

AVICENNA (980-1036) called the "Prince of Physicians." His wonderful description of the origin of mountains fully entitles him to be called the "Father of Geology." His "Canon" is a huge, unwieldy storehouse of learning, in which the author attempts to codify the whole medical knowledge of his time and to square its facts with the systems of Galen and Aristotle. Written in clear and attractive style, this gigantic tome became the fountain-head of authority in the Middle Ages. Yet upon the whole, the influence of the "Canon" upon medieval medicine was bad in that it confirmed physicians in the pernicious idea that ratiocination is better than first-hand investigation.

BICHAT (1771-1802) earliest 19th century exponent of anatomy and scientific medicine in France; creator of descriptive anatomy.

BOERHAAVE (1668-1738) leading physician of his age; now remembered as a great teacher (Haller and Cullen were his pupils) and especially as a chemist.

BOTALLO (b. 1530) A pupil of Fallopius; taught that blood ought to be drawn in all diseases, even in those of a chronic character, and that it should be taken frequently and abundantly. This sanguinary doctrine gained many adherents, especially in Italy and Spain.

**CORVISART (1755-1821)** Napoleon's favorite physician, and the teacher of Dupuytren, Laennec and Cuvier, is now remembered chiefly through his revival of Auenbrugger's work on percussion, a translation of which he appended to the third edition of his "Essay on the Diseases and Organic Lesions of the Heart and the Great Vessels" (1818). As a clinical teacher and pathological anatomist Corvisart exercised an extensive influence. As a diagnostician he enjoyed the greatest reputation.

**CULLEN (1710-1790)** Instrumental in founding the medical school of Glasgow in 1744, and, during his long life, held the chairs of medicine and chemistry at both Glasgow and Edinburgh. He was one of the first to give clinical or infirmary lectures in Great Britain, and his lectures were the first ever given in the vernacular instead of Latin (1757). His "First Lines of the Practice of Physic" (1776-84) was for years authoritative on medical practice, even among the pioneers and "forty-niners" in the Far West.

**HALLER (1708-77)** the master physiologist of his time and one of the most imposing figures in all medical history. He was equally eminent as an anatomist, physiologist, and botanist. He wrote poems and historical novels, carried on perhaps the most gigantic correspondence in the history of science, and lectured and wrote on surgery but never performed an operation in his life. He made a superb medical and surgical and scientific bibliography.

**HARVEY (1578-1657)** the greatest name in 17th century medicine is that of William Harvey, who studied at Padua as a pupil of Fabricius, and whose work has exerted a more profound influence upon modern medicine than that of any other man save Vesalius. The importance of Harvey's work, then, is not so much the discovery of the circulation of the blood as its quantitative or mathematical demonstration. With this start, physiology became a dynamic science.

**HIPPOCRATES (460-370 B. C.)** gave to Greek medicine its scientific spirit and its ethical ideals. The eminence of Hippocrates is three-fold: he dissociated medicine from theurgy and philosophy, crystallized the loose knowledge of the Coan and Cnidian Schools into systematic science, and gave physicians the highest moral inspiration they have. To him medicine owes the art of clinical inspection and observation, and he is, above all, the exemplar of that flexible, critical, well-poised attitude of mind, ever on the lookout for sources of error, which is the very essence of the scientific spirit.

**LOUIS (1787-1872)** founder of medical, as distinguished from vital, statistics. Principal works are his researches on phthisis, his work on typhoid fever which gave the disease its present name, and by his statistical proof that blood-letting is of little value in pneumonia.

**MORGAGNI (1682-1771)** work constitutes true foundation of modern pathologic anatomy, made pathology a genuine branch of modern science.

**PARACELSUS (1493-1541)** His influence was far reaching, and his real services were great. Far in advance of his time, he discarded Galenism and taught physicians to accept chemical therapeutics: he was the first to write on miner's diseases, and the first to establish a correlation between cretinism and endemic goiter; almost the only asepticist between Mondeville and Lister, he taught that nature heals wounds, and not officious meddling; he introduced mineral baths, and was one of the first to analyze them; was great in respect of his own time; does not seem particularly great in relation to our time.

**COOPER, ASTLEY (1768-1841)** He was one of the pioneers in the surgery of the vascular system, in experimental surgery, and in the surgery of the ear.

**COWPER, WILLIAM (1666-1709)** In one of his published works (1702) he described a pair of glands which are to this day known as Cowper's glands. He had a considerable surgical practice, and his papers, published in the "Philosophical Transac-

tions," prove that his attainments in pathology and comparative anatomy were as noteworthy as his knowledge of human anatomy and practical surgery. In 1696 Cowper was elected a Fellow of the Royal Society. In 1697 Cowper published "The Anatomy of Humane Bodies" using the plates of Godfried Bidloo, originally used by the latter in 1685. Bidloo resented this crude piece of plagiarism and an exchange of polemic writings between him and Cowper followed.

The Library has the original edition of Cowper's work and one can readily see that the original Bidloo plate was used, the new title appearing on a shield which was posted over the old title.

**CRUVEILHIER (1791-1873)** His atlases of pathology (1842) are among the most splendidly illustrated books on the subject.

**DUPUYTREN (1777-1835)** The ablest and best trained French surgeon of his time; a shrewd diagnostician, a wonderful clinical teacher, and a good experimental physiologist and pathologist. He first described the condition known as Dupuytren's contracture.

**FABRICIUS (1537-1619)** The very eminent teacher of Harvey; a pupil and successor of Fallopius, who won deserved credit by his teachings regarding the valves of the veins, and his studies in the history of development and in comparative anatomy. How carefully he observed may be judged from the fact that he knew the cavity of the tympanum in the new-born was filled with mucus, a fact rediscovered in our day.

**FALLOPIUS (1523-62)** A loyal pupil of Vesalius, discovered and described the chorda tympani, the semicircular canals, the sphenoid sinus, the ovaries, the round ligaments, and named the vagina and placenta. He was also a versatile writer on surgery, syphilis, mineral waters and other subjects.

**LARREY, BARON (1766-1842)** The greatest French military surgeon of his time, and surgeon to Napoleon's army, and was the first to amputate at the hip joint, doing two successful cases in 1803.

**RUSH (1754-1813)** Ablest American clinician of his time. Gave careful accounts of diseases under his observation, such as cholera infantum, dengue, yellow fever.

The Transylvania Medical School Faculty is well represented in this section with the following:

<i>Bartlett, Elisha</i>	"The Fevers in the United States"
	"Philosophy of Medical Science"
<i>Caldwell, Charles</i>	"Medical and Physical Memoirs"
	"Essays on Malaria"
<i>Cooke, John Esten</i>	"Treatise on Pathology and Therapeutics"
	"Autumnal and Winter Epidemics"
<i>Drake, Daniel</i>	"Principal Diseases of the Interior Valley of North America"
<i>Eberle, John</i>	"Theory and Practice of Medicine"
<i>Mitchell, Thomas D.</i>	"Materia Medica and Therapeutics"

*Anatomy and Surgery:*

**ALBINUS (1697-1700)** One of the greatest anatomic illustrators of his time; held the chairs of anatomy and surgery and medicine at the University of Leyden. His own works are noted for their beauty and accuracy of illustration and for the elegant style of the accompanying text.

**BEAUMONT (1785-1853)** Was surgeon in the U. S. Army. In 1833 his "Experiments and Observations" was published. Beaumont's experiments on the effect of gastric juice upon different foods and the relative digestive values of the latter are the foundation of modern dietetic tables and scales. He was the true leader and pioneer of experimental physiology in our country.



**BELL, CHARLES** (1774-1843) leading British anatomist of the period is now more celebrated as a physiologist and neurologist. Accepted chair of surgery at Edinburgh in 1836.

**BRIGHT** (1789-1858) His "Reports of Medical Cases" (1827) containing his original description of essential nephritis, with its epoch-making distinction between cardiac and renal dropsy, at once established his reputation all over Europe. One of the greatest of modern pathologists and as an original delineator of disease, he ranks next to Laënnec.

**MALPIGHI** (1628-94) the greatest of the microscopists, the founder of histology, who was professor of anatomy at Bologna, Pisa, and Messina. Famed in biology for his works on the anatomy of the silkworm and the morphology of plants, he made an epoch in medicine by his investigations of the embryology of the chick and the histology and physiology of the glands and viscera. His work on the structure of the liver, spleen, and kidneys (1666) did much to advance the physiological knowledge of the viscera, and his name has been eponymically preserved in the Malpighian bodies of the kidney and spleen.

**MONRO, ALEXANDER, Sr.** (1697-1767) A professor of anatomy and surgery and eminent in both branches. He probably contributed more than any single individual to the success and the reputation of the medical school of Edinburgh.

**PARÉ, AMBROÏSE** (1510-90) A distinguished French surgeon who made himself the greatest surgeon of his time by his courage, ability, and common sense. Paré invented many new surgical instruments, made amputation what it is today by reintroducing the ligature, which had almost fallen into abeyance since the time of Celsus; was the first to popularize the use of truss in hernia; did away with the strolling surgeons' trick of castrating the patient in herniotomy; introduced massage, artificial eyes (of gold and silver), and staphyloplasty, and made the first exarticulation of the elbow joint (1536). He described fracture of the neck of the femur and strangury from hypertrophy of the prostate, and was the first to suggest syphilis as a cause of aneurysm. As Dr. Howard A. Kelly has pointed out, he was probably also the first to see flies as transmitters of infectious disease. In obstetrics, it was his description and use of podalic version that made the procedure viable and practicable, and he had the courage to induce artificial labor in case of uterine hemorrhage. In dentistry, he introduced reimplantation of the teeth, and his little treatise on medical jurisprudence (1575) was the first work of consequence on the subject prior to the "Methodus testificandi" of Codronchi (1597).

**PETIT** (1674-1750) Leading French surgeon of the early 18th century; was the inventor of the screw-tourniquet, gave the first account of softening of the bones and of the formation of clots in wounded arteries, and made improvements in amputations, and herniotomy. He was the first to open the mastoid process.

**SCARPA** (1747-1832) a great anatomist and surgeon; equally skilled as orthopedist and ophthalmologist. Remembered for the triangle in the thigh which bears his name, his important treatises on hernia and eye diseases, and his shoe for club-foot.

**SOMMERRING** (1755-1830) wrote a monumental treatise on anatomy; made most important researches on the brain, the eye, the ear, nose and throat, and hernia, but is now best remembered for his remarkable accuracy in anatomic illustration and by his classification of the cranial nerves.

#### *Physiology:*

**HUNTER, JOHN** (1728-93) Eminent as a pathologic and comparative anatomist, and an investigator of the subject of inflammation and the blood. Masterpieces; "Natural History of Human Teeth" (1771); "Venereal Disease" (1786); "Treatise on Blood, Inflammation and Gun Shot Wounds" (1794).

HEWSON (1739-74) His "Experimental Inquiry into the Properties of the Blood" (1771) established the essential features of the coagulation of the blood.

PINEL (1745-1826) Stands high in medical history as the first to treat the insane in a humane manner. Real founder of the modern "open door" school of psychiatry.

*Natural History:*

This section should be particularly noted for its holdings. It is likely due to the fact that Rafinesque held the chair of Natural History and Botany as well as Librarian and helped increase this collection.

BONAPARTE, Charles Lucian; American Ornithology, 4 v.

BLUMENBACH Celebrated German naturalist: Founder of anthropology; professor of anatomy and medicine at Göttingen; first to teach natural history on basis of comparative anatomy; proposed the division of the human species into five races.

CUVIER Founder of science of comparative anatomy; celebrated French Naturalist.

GATESBY English naturalist. Library has his handsome elephant folio on "Natural History of Carolina, Florida, and the Bahama Islands."

DARWIN English Naturalist.

LAMARCK Celebrated French naturalist; one of the founders of the doctrine of biological evolution.

LINNE Celebrated Swedish botanist and naturalist; founder of the Linnean system.

MICHAUX, F. Andre and Andre—French naturalists.

LEEUVENHOEK Dutch microscopist and naturalist.

SWAINSON English naturalist.

*Scientific Periodicals:*

Quarterly Journal of Science and the Arts, 22 v. London, 1816-1827.

Tilloch's Philosophical Magazine, 65 v. London, 1798-1825.

Journal of the Franklin Institute, 21 v. Philadelphia, 1828-1838.

Silliman's Journal of Science and Arts, 49 v. New Haven, 1812-1845.

*Medical Periodicals:*

Medical and Philosophical Commentaries, 12 v. London, 1773-1778.

Medical and Physical Journal, 24 v. London, 1799-1810.

Medical Repository, 14 v. New York, 1804-1811.

North American Medical and Surgical Journal, 12 v. Phil. 1826-1831.

Western Medical and Physical Journal, 10 v. Cincinnati, 1827-1837.

Pennsylvania Journal of Medicine, 12 v. Lexington, 1828-1839.

Medico-Chirurgical Transactions, 22 v. Lexington, 1828-1839.

Philadelphia Journal of the Medical and Physical Sciences, 14 v. Phil. 1820-27.

American Journal of Medical Sciences, 26 v.: n. s. 10 v. Phil. 1827-1839. 1841-1845.

Medico-Chirurgical Review, 42 v. New York, 1823-1845.

Edinburgh Medical and Surgical Journal, 63 v. Edinburgh, 1805-45.

The Lancet, 35 v. London, 1823-1845.

London Medical Gazette, 20 v. London, 1827-1839.

Western Lancet, 16 v. Cincinnati, 1842-1853.

*Fathers of Medicine:*

DIOSCORIDES' work is authoritative source on the materia medica of antiquity; first to write on medical botany as an applied science.

GALEN (131-201) founder of experimental medicine; was first and only experimental physiologist before Harvey.

RHAZES (860-932) his description of small pox, measles first authentic account in literature.

FRACASTORO (1484-1553) In his work "De Contagione" he states the modern theory of infection by micro-organisms.

HOFFMANN, FRIEDRICH (1660-1742) Born in Halle; was an eminent German physician, and years later was called to the newly founded university of Halle as professor of anatomy, surgery and practice, as well as of physics and chemistry. As a chemist he acquired lasting reputation by the numerous analyses of mineral waters, as well as by his investigations of the ethereal oils. In these studies he made the discovery of some special remedies, with which, like Stahl, he carried on a lucrative business. He was one of the most famous professors of his day, and, accordingly, brought his youthful university into a most flourishing condition. In 1709 he was called away to Berlin as ordinary physician to King Frederick I, but returned to Halle as professor. He was an extremely busy and fortunate practitioner, who even Boerhaave declared his own equal. He was an extraordinarily voluminous writer. An edition of his Latin works comprises 27 octavo volumes. His chief work was entitled "Medicine Rationalis Systematica" (1718-1740). He was the originator of the prescription which has come down to modern times "Hoffmann's anodyne."

In Sir Clifford Allbutt's view, Hoffmann was the greatest of the iatromechanists and the first to perceive that "pathology is an aspect of physiology." He left an original description of chlorosis (1730), and was one of the first to describe rubella (1740).

RUYSCH (1638-1731) advanced anatomy by the formation of anatomical collections, one of which was brought into Russia by Peter the Great at an expense of about \$75,000. Also noted for the quaintly posed skeletons of his anatomical drawings.

WINSLOW (1669-1760) his anatomic work was authoritative text-book for nearly a century.

I have attempted to develop, in a small way, the origin and growth of Transylvania University, its Medical College, the faculty, and the Medical Library. As has been stated, this Library contains more than 10,000 valuable and ancient books, so it has been impossible in this short survey to give a fully detailed list, so I have presented a few of the most noteworthy authors, books and other publications. Many of these books are first editions. This library is housed in a brick and wooden building which is not fire and theft proof, and if we should have a fire all of them would probably be destroyed. Many of the books are in a good state of preservation, many need repairs and many need rebinding.

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# NEWER CONCEPTS IN THE TREATMENT OF THE PARALYZED PATIENTS DUE TO WAR-TIME INJURIES OF THE SPINAL CORD\*

## OUTLINE OF PLAN AND STATISTICAL ANALYSIS

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ONE OF THE INEVITABLE side-effects of war is the production of injuries which render many soldiers permanently handicapped and the unfortunate individual with paraplegia which was caused by damage to the spinal cord is unquestionably among the most pitiful. He is shadowed by the inevitable prospect of a fatal outcome in one to ten years which is usually brought about by the ravages of continuous infection of the urinary tract and its complications, and, in addition, by all the moral and physical retrogressive changes of severe chronic malnutrition. The method of treatment has usually consisted of those measures that would keep the patient in some degree of comfort during the few remaining months or years of this life. Fortunately, such a defeatist attitude has been prohibited by regulation during the war just ending.

During this conflict approximately 2,000 soldiers received spinal cord injuries as a result of the use of high velocity explosives and increasingly destructive ordnance products, and the Navy's figures probably total 500 additional cases (complete figures will not be tabulated for many months). The percentage may be low compared with the figures of previous wars (American Civil War, 0.25 per cent; Spanish-American War, 0.55 per cent; Balkan War, 0.6 per cent; World War I, 0.53 per cent), but when the total number of combatant troops are calculated the figure may rise above those indicated. This is due undoubtedly to the increased violence and damage of destructive forces used in this conflict.

The mortality rate shows a marked decrease from an all-time high in the Balkan Wars of 95 per cent (average other wars, 50 to 60 per cent) to approximately 20 per cent in this war. This remarkably low figure is the most commendable result of the organization and activities of the neurologic surgeons who sent their best trained specialists to the most forward echelons, at which point definite procedures were carried out. However, this lowering of the battlefield mortality produced a marked increase in the number of patients to be cared for in the General Hospitals in the United States, which at the present time totals 1,300 paraplegics for the Army alone. Approximately one-third of these will be discharged to their homes in the next few months, leaving a group of 800 or 900 to be cared for in veterans' facilities.

It is our purpose at this time to point out ways and means by which these individuals can be successfully treated and restored to the community capable

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of self-support and some type of ambulation by which they can move themselves independently from one place to another. In such a scheme the generous pension granted by the government should serve only as a form of health insurance not obtainable elsewhere. Our plan is a joint project representing the value and results of specialization to its finest degree and by these activities the patient has reaped the highly desirable benefits.

#### THE PROBLEM

Confronted with a sizable group of what were so recently healthy and happy American youths who now had become paralyzed to some degree in the lower extremities and a few in the upper extremity as well, who were unable to control normal urine and bowel function, and who were faced with the formerly inevitable fatal complications of urinary tract infection of some intermediary condition no less serious, we stopped to survey the problem. Certainly a more dismal and discouraging problem was seldom presented before any group of physicians.

If our desideratum was considered to be the restoration of that happy, healthy American youth to the ability to achieve financial and economic independence, to use his remaining muscle power with the aid of mechanical means to restore independence of movement, and to develop an adequate control over bowel and bladder function, then a certain degree of happiness and good health based on readjustment to such a tragic condition would become easier to obtain. Surveying this picture as a whole, we divided the treatment of an individual with injury to the spinal cord into three phases from the standpoint of medical installations in the military services and to a large degree the same divisions could be applied to civilian life:

I. *Initial and Early Treatment Phase.*—This begins with the treatment on the battlefield after wounding, transportation to the rear, and the first definitive treatment rendered in the Evacuation Hospital. It would cover the period of waiting in a numbered General Hospital until evacuated back to the United States.

II. *Corrective Treatment Phase.*—Upon arrival at a General Hospital in this country, malnutrition, decubitus ulcers, urinary infection and depression had usually developed and the second phase covers the correction of these conditions. In addition to these corrective measures any necessary neurologic surgery operations were performed for the removal of foreign bodies from the region of the injury and for the relief of pain, troublesome reflexes and spasticity. Attempts were made immediately to put the patient in a wheel chair soon after arrival as the first step to independent ambulation. Any associated injuries were dealt with, including closure of colostomies, removal of foreign bodies and completion of treatment of fractures. A well-planned educational, recreational and prevocational training program completed a very full day's activities throughout this period.

III. *Ambulation or Economic Security Phase.*—Upon completion of the procedures enumerated in Phase II, the more serious aspects of adjustment to

future life were now dealt with. To assist with ambulation some reconstructive orthopedic procedures were needed to provide stabilization of joints and return of motion. A set of exercises to provide strong trunk and upper extremity muscles were carried out vigorously and regularly. Special training and instruction in the use of braces, crutches, traction and special walking and sliding devices to teach the individual to sit, stand, fall, drive an automobile and handle himself in the toilet and bathroom were given. Instruction in a wide range of jobs, positions, business opportunities, technical trades, professional and subprofessional activities were insisted upon to insure the earning of an income sufficient for the needs of the individual and his family.

#### THE PLAN

In an Army General Hospital our chief part in achievement of such results for these patients has been the professional care indicated in the second and third phases. This report applies particularly to those procedures carried out in Phase II, because the end-results are near completion while the measures described in Phase III are still in the process of being carried out.

Any such program must have its single director in whom complete responsibility is vested because of the overlapping of the many special fields of professional interest involved. One might suggest the general practitioner who always has the entire patient as his chief field of interest, but the need for specialists has done away with those prospects. According to regulations these patients are sent to a Neurologic Surgery Center and while undoubtedly this specialist should play the leading part in this program, he is immediately confronted with many problems outside this field. The urologist has the most active part in the treatment during the early stages because of the constant care needed to make any type of urinary drainage operate properly. The internist has his part in the correction of nutritional and vitamin deficiencies; the surgeon, or plastic surgeon, has the decubitus ulcers and other surgical conditions to deal with; and the orthopedist treats the fractures and supervises the mechanical means of walking. We believe one condition to be absolutely essential in assigning a director for this program, and that is that the doctor must have a sincere humanitarian as well as professional interest in these patients to the extent that he will leave nothing unturned to achieve the results desired. Each hospital has had to make this selection on the basis of the qualifications of its staff members, but once put in charge the Director must have the entire responsibility for seeing that all specialists involved carry out their part without delay. In addition to the professional advantages which follow this fixed rule, a tremendous boost to the morale of each patient results because of the strong doctor-patient relationship that it fosters. Knowing that one instead of many doctors is in charge of his case, and that this doctor will call on all other specialists freely, and that he will also assist in the solution of their many personal problems, has provided the springboard from which these mentally and physically ill patients can begin their long trek back to a normal existence.

### CONCLUSIONS

A plan used for the treatment of patients having sustained injuries of the spinal cord in war-time is presented and the details discussed. This covers the second and part of the third phase of the restoration of these individuals to a life of independent ambulation, an adequate control of bladder and rectal function, freedom of pain, relief of spasticity and troublesome reflexes, and an education or training adequate to make the individual self-supporting. This plan has been in use for 15 months, and the results are gratifying. Solution of specific problems in the various specialty fields will be discussed by each department.

### STATISTICAL ANALYSIS

During the past 15 months 77 patients with injuries of the spinal cord have been received for treatment at the Newton D. Baker General Hospital. There are at the present time 250 patients in hospitals of the Fifth Service Command, and it is estimated that there are 1,300 in the General Hospital system in the United States. While the statistical compilations for the war recently ended will not be completed for many months, this number added to the fatal cases represents a percentage quite similar to that of other wars (World War, 0.53 per cent; American Civil War, 0.25 per cent; Spanish-American War, 0.55 per cent, and Balkan War, 0.6 per cent).

*Etiology:* Damage to the spinal cord in these individuals was produced on the battlefields in the European and the Pacific Areas for the most part (90 per cent) by high velocity bullets (17), shell fragments (50), and mine explosions (two). Considering the tremendous violence and destructive force of modern instruments of war, no part of the body could hope to escape injury, and the cord with its bony protection is no exception. Motorization of the vehicles of war has contributed its share of serious back injuries and includes the truck, jeep, airplane and command car in this series (one each). Two soldiers fell considerable distances and one dived into shallow water.

*Associated Injuries:* Over half of these patients (45—58.4 per cent) sustained serious injuries to other parts of the body at the same time, demonstrating more evidence of frightful effects of weapons used today. These included bullet and fragment wounds of the soft-parts, fractures of long bones, and injuries to the head, chest and abdominal organs.

*Level and Degree of Injury:* The cervical region was injured in one-fifth of the cases (15—19.7 per cent), and cauda equina of lumbar (18—23.6 per cent) and sacral (5—6.5 per cent) areas in 30 per cent. The remaining 39 (50.5 per cent) were injured in the region of the dorsal spine. Complete transection of the cord was produced in 29 patients (37.6 per cent) and incomplete or partial in 44 patients (62.3 per cent). Neurologic survey has revealed some more or less bizarre findings in certain cases which has made the final decision as to the degree of the lesion problematic.

*Age:* Considering the usual idea of youth, the average age (25.4 years) seems high. One man of 40, and a boy of 19 are included in this group.



*Marital Status:* Twenty-two patients were married (28.5 per cent), and nine of these had children.

*Education and Work:* Thirty-five patients had received high school education, 16 grade school, and five were college students. Fifty-two (66 per cent) were laborers and white collar occupations of the others included musicians, clerks, accountants, and salesmen. Five were officers in company grade. A major general in another hospital was injured in a plane crash.

*Nutritional Status on Admission:* A high percentage of patients received in this country (74 per cent) had developed a serious degree of emaciation, with an average weight-loss of 42.5 pounds per person. Since these patients always received a high priority for food rations in all installations, this condition must be ascribed to other causes, and chief among these is the severe depression and loss of appetite that follows such a tragic event. Moderate to severe secondary anemia existed in this same group as shown in average red cell counts, hemoglobin and hematocrit. Determinations by the micro-Kjeldahl method showed 36 patients (46.8 per cent) to be in negative nitrogen balance with reversal of the albumen-globulin serum ratio, and with excess calcium excretion in the urine.

*Decubitus Ulcers:* Forty-four patients (57.1 per cent) had decubitus ulcers on arrival, due undoubtedly to the inability to render adequate nursing care at all times and places. The exigencies of travel in war-time, with its inevitable delays and inconveniences, have remained beyond control. Since it is known that a decubitus ulcer will develop in a matter of hours in a nonparalyzed individual, such occurrence in this group will always remain high. The ulcers were multiple in 31 patients, averaging from two to 11 per individual. Patients transported by air were invariably in better condition as regards nutrition and decubitus ulcers than those moved by other means of travel.

In this large group of patients the factor of loss of proteins in the secretions from the ulcers presented an additional nutrition problem. Using the methods of Cotui and Mulholland, the protein loss was found to be:

50 Gm. plus —	2 cases
40 Gm. plus —	4 cases
30 Gm. plus —	4 cases
20 Gm. plus —	8 cases
10 Gm. plus —	9 cases
5 Gm. plus —	8 cases
Less than 5 Gm. —	2 cases

*Bladder Status:* Since regulations required it, a suprapubic cystotomy had been done before evacuation to this country, in all patients not voiding except one (33 voiding, 43 cystotomies). Urinary infection had developed in all patients except three, and the causative organism was usually one or more of the gram-negative group (*Aerobacter aerogenes*, *B. proteus*, *Esch. coli*,

*Staphylococcus aureus* and *albus*, *B. coli* (intermediate), *B. pyocyaneus*, pericolon, gamma *Streptococcus*).

*Neurologic Status:* Most of the findings are presented in a subsequent report, but as a factor to be dealt with immediately upon admission, 13 patients (1.6 per cent) had severe pain, 10 (1.2 per cent) had troublesome reflexes referred to also as spinal or mass reflexes, and 12 (1.5 per cent) had a marked degree of spasticity. Forty-four patients (57.1 per cent) had had primary laminectomy performed before evacuation.

*Mental Status:* While some degree of depression was to be expected when patients having had such a catastrophic injury first return to their home land and are visited by their families, yet only one psychosis was observed.

*Ambulation on Admission:* Since all patients were received by litter, and unless serious complications were present, everyone was expected to be placed in a wheelchair within a month after admission.

*Mortality:* There has been one death in this series (1.3 per cent). This remarkably low figure stands as fine tribute to the personnel who rendered the professional and nursing care to these unfortunate individuals. The cause of death in this instance was the complications of ascending pyelonephritis and pulmonary abscess.

#### SUMMARY

The essential vital statistics of a series of patients having injuries to the spinal cord are presented. The treatment of these patients will be presented in subsequent reports by the special sections involved.

# NEWER CONCEPTS IN THE TREATMENT OF THE PARALYZED PATIENT DUE TO WAR-TIME INJURIES OF THE SPINE

## II—NEUROSURGICAL COMPLICATIONS\*

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DURING THE PAST YEAR AND A HALF we have had the opportunity of observing a series of 77 cases with war injuries of the spinal cord resulting in either complete or partial paralysis of one or more extremities and varying degrees of bladder and bowel dysfunction. On the basis of our experience, the conclusions are drawn that the most frequent neurosurgical complications in this type of patient are retained foreign bodies in close proximity to the spinal cord or peripheral nerve roots, intractable pain and uncontrolled spinal reflexes.

The interest of the Army Medical Corps has been aroused in these problems and much has been accomplished toward clarification of thinking and unification of treatment. Much remains to be accomplished and important contributions are forthcoming. The purpose of this paper is to present conclusions drawn from our experiences.

The occurrence of retained foreign bodies in, or close to the spinal canal or nerve roots, in our series was frequent, occurring in 12 cases. Indications for removal were grouped into four categories, the most frequent of which was the presence of intractable pain. The next most frequent indication was the presence of a foreign body either in, or in close approximation to, the cauda equina. The location was considered an indication for removal even in the absence of pain in hopes that removal of scar tissue would permit some recovery of function or to prevent the development of increasing chronic adhesive arachnoiditis with pain or decreased function at some future date. The presence of an intraspinal foreign body in any location was considered to be an indication for removal either in complete or partial transections. By this it was hoped that the development of sequelae due to continued scar tissue formation could be prevented. In addition, the difficulty in clinically recognizing a complete from an incomplete transection is well known and it was hoped that some clinical improvement might take place following removal of an intraspinal foreign body. A persistent draining sinus was the final indication for foreign body removal in our series and as this indication is fundamental, nothing further need be said on this matter.

The results insofar as relief of pain was concerned were on the whole satisfactory. Of the five cases in which the only indication for removal of the foreign body was the presence of pain, it is significant to note that no

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further procedure for relief of pain has been necessary. Complete relief, however, did not occur in all cases. Evaluation of results in those cases with foreign bodies in, or in close approximation to, the cauda equina has been difficult. Of the three cases falling in this category, none have actually improved in function but, on the other hand, there has been no decrease in existing function nor has any case developed pain. We believe that only because of the limitations in numbers of our series have we failed to obtain some improvement in function following the removal of a foreign body and lysis of the cauda equina. We cannot properly evaluate results in those cases in which the only indication for removal of a foreign body was its intraspinal position, except to state that in neither of the two cases in this category has improvement of function occurred, although in neither case has further unpleasant sequelae developed. In two cases draining sinuses promptly healed following removal of a foreign body.

It was early recognized in our experience that the problem of pain in the paralyzed patient was a difficult one. Because of generalized debility, the threshold to pain in many cases was unquestionably low. In certain cases however, persistent pain was present and contributed largely to the patient's debility. Request that the patient describe his type of pain led to a wide variety of responses. These differed from a simple radicular or root-type to generalized burning, aching or pulling sensation usually in an extremity but occasionally in the bladder or rectum. Recognition of the etiologic agent such as a foreign body in close approximation to the central or peripheral nervous system was sometimes fairly simple but in other cases the causative factor seemed somewhat more obscure. It was recognized that following injury to the spinal cord, scar tissue was inevitable and that in certain cases lysis of this scar tissue would result in relief of pain. By and large, however, this type of procedure, to be effective must be extensive and it was evident to us that these debilitated cases would not easily tolerate any extensive procedures and as the relief of pain in certain cases was almost a life-saving procedure, we chose spinothalamic cordotomy as the procedure of choice provided that the more simple and well-known procedures proved unsatisfactory. We avoided alcohol injection of the spinal subarachnoid space because of the danger of upsetting a bladder physiology which usually was already precarious.

The results of our program for the relief of pain have been eminently satisfactory. The greatest single factor has been improvement in general nutrition amongst this group. Unquestionably, the tolerance to pain rises with decrease in debility. Three cases of spinothalamic cordotomy were performed, and in two cases the relief of pain has been dramatic. Both rapidly gained weight and are now ambulatory with braces. The third case continues to complain periodically but no longer requires narcotics. In evaluating results of the entire pain program, the amount of narcotics necessary on the ward may be considered to be the criteria of success or failure. Narcotics and the fear of drug addiction in this group of patients no longer constitute an important problem.

The third major neurosurgical complication existing in a large percentage of paralyzed patients is uncontrolled spinal reflexes. The variety of these reflexes, from simple flexion to the widespread overflow of the mass reflex lead to much confusion, and the tendency has been to lump them all together under the single item "mass reflex." However, as long as specific variations are hidden by such a vague generalization, thinking will tend to be obscured and progress in determining why certain reflexes occur in one patient and not in another will be delayed.

The classical descriptions of reflex activity in spinal injuries were published by Sherrington,<sup>1</sup> Walshe,<sup>2</sup> and Head and Riddoch.<sup>3</sup> Their basic conclusions have not been disproven, although they are questioned in some quarters because of the difficulty in explaining varied reflex findings by reference to classical concepts. Six rather definite spastic types are recognizable.

TABLE I  
SPASTIC REFLEXES

Name	Features of Reflex	Type of Stimulus	Reflexogenic Area	Purpose
1. Flexion (simple)	Flexion at hip, knee, and dorsiflexion at ankle and toes. May be contraction of abdominal muscles on same side	Normally painful; cutaneous	Plantar surface of foot especially, but stimulus anywhere else on thigh or leg may produce it	Removal of the part from cause of discomfort
2. Extension	Extension of thigh, knee, and plantar flexion at ankle. Hamstrings contracted. Adductors of thigh usually contracted	(a) Muscle stretch or (b) Skin stroke	(a) Stretch of any extensor muscle, or (b) Stroking of skin, especially inside of thigh or perineum	(a) To maintain position (b) Sexual reflex, producing posture of copulation
3. Crossed extension	When one limb engages in a flexion reflex the opposite limb extends	Same as for flexion reflex. (1)	Same as (1)	To give support as ipsilateral limb is withdrawn from stimulus
4. Extensor thrust	Extension as in (2)	Pressure	Pressure against toe pads or sole with knee in slight flexion	To maintain posture
5. Reflex stepping	Production of extensor thrust on one side produces flexion of opposite leg. These movements may then continue alternately	Stretch of gastrocnemius when knee is flexed	Proprioceptors of gastrocnemius	Maintenance of posture in progression
6. Mass reflex	Flexion of ipsilateral limb. There may be flexion or extension of contralateral limb. Contraction of bladder, sweating. (Flexion of limb coupled with one or more of the purposeless manifestations will suffice)	Painful or innocuous skin stimulation, or stimulation of muscles and tendons (proprioception)	Skin of thigh and lower abdomen, perineum or deep structures of lower extremity (proprioceptive)	Partly to remove leg from threatening stimulus, but remainder of reaction is without purpose in primates

These are simple flexion, extension, crossed extension, extensor thrust, reflex stepping and mass reflex. Table I is presented to describe the features of the reflexes associated with transverse lesions of the spinal cord. It is meant as a working classification and certain physiologists may question its exactness, yet, if it serves to bring some order out of chaos, it will have served its purpose.

All of these reflex activities have been observed in our patients except the extensor thrust. Attempts have been made to find the reasons for variation in reflex response from patient to patient and they have not been successful. Except for the uniform flaccidity of cauda equina lesions, one can find no reflex characteristics which are definitely typical of the level or degree of severity of the cord lesion. Of two patients having lesions of the same age, at the same level, and of approximately equal severity, one may have spastic reflexes while the other is flaccid; or if both are spastic, one may be in flexion and the other in extension. Thus, there is a definite need for critical reexamination of accepted concepts and especially for correlation of detailed pathologic findings in the spinal cord with observed clinical phenomena whenever the opportunity arises.

One of the conclusions drawn by the above mentioned authors, and confirmed in our experience, is that extensor reflexes are generally observed in anatomically incomplete lesions of the spinal cord. Except for an occasional variation, the hip, knee and ankle joints are strongly extended and resist passive flexion. Accompanying clonus is frequent. This fact should make one cautious in treating extensor spasms by a destructive operation, such as anterior rhizotomy,<sup>5</sup> which would permanently preclude the possibility of spontaneous recovery of function.

In trying to fit the clinical findings of paraplegics into a neurologic pattern one must not lose sight of the fact that they may have multiple or widespread lesions rather than a single restricted lesion at the point of injury. This is true for closed injuries of the spine as well as for gunshot wounds. Discontinuous areas of hematomyelia may occur extending from the medulla to the conus medullaris. That less extensive hematomyelia is not uncommon in paraplegic soldiers, is evidenced by the findings of isolated muscle atrophy and other neurologic changes which cannot be explained on the basis of a single lesion at a given level. This helps to confuse the reflex pattern.

It is well not to regard a given reflex state as necessarily fixed, even when there are strong flexor or extensor spasms in obviously severe lesions. Some patients will show a gradual reduction in this uncontrolled activity until finally their extremities are almost, if not quite, flaccid. Sherrington took note of this phenomenon and ascribed it to "isolation dystrophy" in the distal segment of the cord. We are unaware of any adequate pathologic study of this condition and suspect it to be a progressive effect of initial widespread trauma. That the cases observed by Sherrington's followers in World War I may not have been as free of sepsis nor as adequately nourished as similar patients are today may also have been a factor in causing the reflex activity to subside, for it is well known that toxemia may depress reflex activity; but that reasoning can hardly be applied to the cases seen today. Whatever the cause for the subsidence of spastic responses in the legs, whenever it occurs it is a great boon to patient and doctor.

As this remark indicates, our interest in the reflex activity of the traumatized spinal cord is not purely academic—these reflexes may present thera-

peutic problems, both in partial and complete lesions. In a small but troublesome minority there will be flexor and extensor spasms of such strength as to greatly hinder or prevent ambulation—which is the primary goal of all paraplegics.

Generally speaking, it seems best to follow a conservative course in treating these spastic conditions because of the hope of spontaneous remission. This has been noted in total transections as well as in partial lesions. The treatment during this period should consist of splinting, physiotherapy, and any other simple method that particular circumstances indicate. Unfortunately, skin traction can seldom be employed because of the danger of pressure sores when such traction is used on partially or completely anesthetic skin. In one severe case with an incomplete lesion and beginning contractures we used Kirschner wire traction, and although it served the purpose very well, the frequent spastic jerking of the leg caused considerable pain at the site of the wire. With flexion reflexes one must guard against contractures at the hip as well as at the knee. With this in mind, it has been very helpful to have the patient lie on his abdomen a part of each day, with legs held flat by a folded sheet tied beneath the bed.

We have had some experience with curare, having used Squibb's "intocostrin" in six cases. It was given intramuscularly in doses starting at 1.0 mg. per kilo of body weight and increasing gradually to almost 3.0 mg. per kilo. The results were not striking and the only conclusion to be reached from our experience is that the brief and moderate improvement in spasticity produced by the curare is hardly useful except as an adjunct to other therapy, such as splinting, traction and passive exercise. We are still using it for this purpose and believe it has a definite place in the therapy of these patients.

The proper dose of curare must be determined individually for each patient. Unfortunately, the larger doses which produce the greatest relaxation of the extremities also produce so much drowsiness, weakness and double vision that the patient is unable to take an active part in his therapy program for the remainder of the day. It, therefore, seems better to use only moderate doses and to be content with less relaxation while retaining the continuous participation of the patient in his physical training. Only when moderate doses are used does there seem to be any relaxation of the spasticity without interference with the remaining voluntary motor activity, as some authors have described.<sup>4</sup> As there is a small carry-over of the curare effect for several days, single injections have been given at two-day intervals.

When time and conservative measures do not bring about sufficient relaxation of flexor or extensor reflexes to permit ambulation, more radical therapy can be considered. When strong extensor reflexes are present there is usually such marked adductor spasm that one leg crosses over the other. This, of course, prevents walking, whether with braces and crutches or by voluntary power. In those patients with some voluntary motor function present in the lower extremities, relief of the adductor spasm often makes them ambulatory without the use of braces. Furthermore, as extensor spasms commonly

begin with contraction of the adductors, denervating these muscles may radically change the reflex picture and result in less spastic extremities. This desirable result can easily be obtained by dividing the anterior and posterior branches of the obturator nerve, thus, paralyzing the principal adductor muscles. Mere neurectomy should not be considered sufficient, however. During the months of adductor contraction, fibrotic changes have probably occurred not only in the muscles but around the hip joints as well. It is strongly recommended, therefore, that adduction splints be applied immediately after the operation and that their use at night be continued for some months. In those patients in whom it seems desirable to hasten spontaneous improvement by a temporary paralysis of the adductors, the obturator nerves can be crushed in a clamp, but then it must be expected that the muscles will function strongly again in a few months. We have relieved adductor spasms in two cases by these procedures and in both cases the patient was able to stand erect. In an earlier case, an incapacitating clonus practically disappeared over a period of several months of ambulation.

In patients who have severe flexor or extensor spasms with what appears to be a complete cord lesion, and this fact should usually be verified by a laminectomy—relief can be obtained by anterior rhizotomy. This procedure will not only produce flaccid legs, but will also stop much of the hyperactive bladder activity which is so troublesome when spastic paraplegics move about.

Anterior rhizotomy of the appropriate nerve roots, as described by Munro,<sup>5</sup> at times becomes the procedure of choice in patients with spastic contractures and uncontrolled spinal reflexes. We have employed this procedure in three cases successfully. In one case it was a life-saving procedure. Two of our cases are now ambulatory with braces. The third case may require tenotomies for the release of fixed contractures due to fibrosis around one knee. We are aware that selective spinal subarachnoid injections of alcohol have been advocated to control the less severe cases with spastic reflexes. Having had no experience in this procedure, we can offer no constructive criticism.

#### SUMMARY

Our experiences in the treatment of a series of spinal cord injuries have been interesting and illuminating. We have drawn certain conclusions, as presented above, but we recognize that the challenge has presented itself for further advances in a field which, a few short months ago and with few exceptions, was considered a hopeless proposition.

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# METHODS OF CLOSURE OF DECUBITUS ULCERS IN THE PARALYZED PATIENT\*

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DURING THE PAST 12 MONTHS, it has been the authors' privilege to study a group of 80 cases of paraplegia due to war injuries of the spine. One of the most difficult of the many problems presented by this group of patients was the care of decubital ulcers which were present in a high percentage of the group. In consideration of the problem, a review of the information available in regard to decubital ulcers was carried out.

The factors responsible for the healing process of a decubital ulcer are the relief of pressure from the involved area, control of extraneous moisture,<sup>1</sup> a positive nitrogen balance,<sup>2</sup> and adequate vitamin intake.<sup>3, 4</sup> If these variables are considered and appropriate measures taken to correct deficiencies, it is recognized that healing will take place over a long period of time but at the expense of a considerable amount of nursing care to a slowly granulating and epithelizing surface. It is believed, however, that the presence of a large healing ulcer may, in itself, contribute to the patient's general debility and thus may be a factor in the slowness of healing. Mulholland, Co Tui, *et al.*,<sup>2</sup> studied the nitrogen balance in 35 cases with decubital ulcers, and concluded that the ulcers began to heal only when the blood serum protein began to rise and the nitrogen balance changed from negative to positive. They measured the protein output of one ulcer over a 24-hour period and found that during that period the patient lost 5.56 Gm. of protein from the ulcer. We, likewise, measured the protein output of decubital ulcers by collecting the débris and secretions for 24 hours on a nitrogen-free cellulose pad and then determining the nitrogen content by the Kjeldahl method. In one of our patients, with five ulcers of varying sizes, the 24-hour protein loss from these ulcers was 50 Gm. Thus, it may be seen that there is an appreciable loss of protein from decubital ulcers.

Because of these facts, we determined to attempt surgical closure of decubital ulcers. As a basis of experience, a search of the literature revealed that Lamon and Alexander<sup>5</sup> had reported one case of decubital ulcer treated by excision and closure. Furthermore, we became acquainted with the successful work of Major W. B. Scoville, at Cushing General Hospital, utilizing a method of secondary closure of large ulcers.<sup>6</sup> Foman, in 1939, states that small decubital ulcers could be excised and closed after becoming surgically clean. He also

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\* Read before the Fifty-seventh Annual Session of the Southern Surgical Association, December 4-6, 1945, Hot Springs, Virginia.

stated that larger ulcers should be closed by skin grafting but no references were given and no cases cited in which this method was employed.<sup>7</sup>

In our series are included 70 cases of decubital ulcers which have been surgically closed by one of three methods. Twenty-four cases in this series were supervised by Captain Barker, at Nichols General Hospital, Louisville, Ky., and Ashford General Hospital, White Sulphur Springs, W. Va. The staffs of both hospitals gave unlimited coöperation. Excision and suture was employed in small ulcers, rotation flaps were utilized in large ulcers over the trochanters, and split-thickness skin grafts employed on large ulcers over the sacrum.

#### PREOPERATIVE MANAGEMENT

The preoperative management of a patient with a decubital ulcer consists of attempts to remove the patient from a debilitated state by means of adequate protein, vitamin and caloric intake. The preoperative care of a decubital ulcer consisted of attempts to acquire a clean granulating base. No attempt has

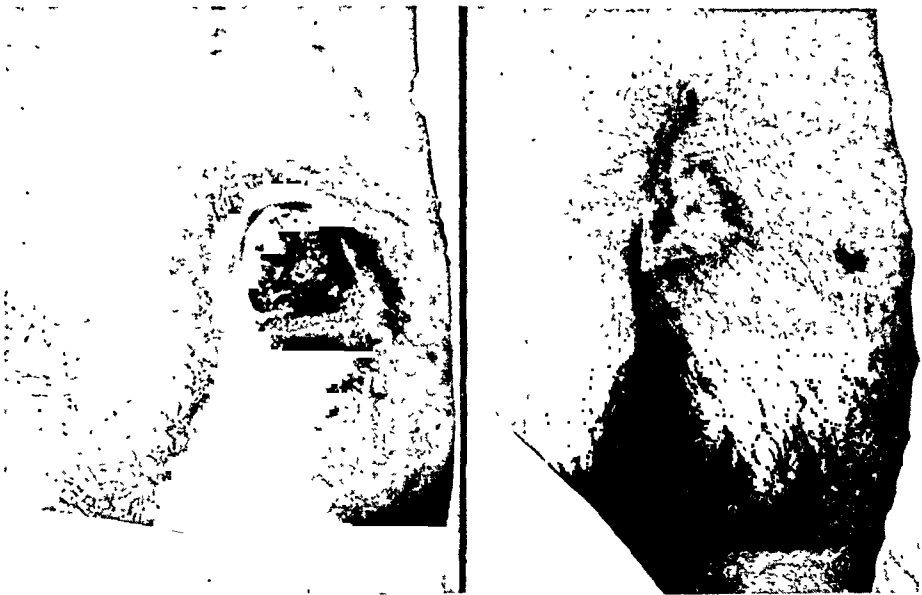


FIG. 1-A

FIG. 1-B

FIG. 1.—(A) Preoperative small sacral ulcer.

FIG. 1.—(B) Nine months postoperative.

been made to make an ulcerated area bacteria free. Various preparations were used to apply locally on the ulcer, as seemed indicated by the amount of slough and degree of reaction around the affected area.

#### OPERATIVE MANAGEMENT

In the main, we were confronted by three different types of ulcers. The small ulcers over the sacrum and trochanters were closed secondarily (Fig. 1 A and B). The large ulcers of the trochanteric region were closed by means of rotation flaps with undermining (Figs 2 A, B and C). The most difficult problems were the large ulcers of the sacrum in which closure was attempted by means of split-thickness skin grafts. Typical results of this procedure are demonstrated in Figures 3, 4 and 5.

## DECUBITUS ULCERS

In closure of the small ulcers an attempt was made to remove all the devitalized tissue and all of the scarred tissue surrounding the ulcer by surgical excision. In all these cases, a good five-minute cleansing of the ulcer area was done with white soap and water. The area surrounding the ulcer was undermined

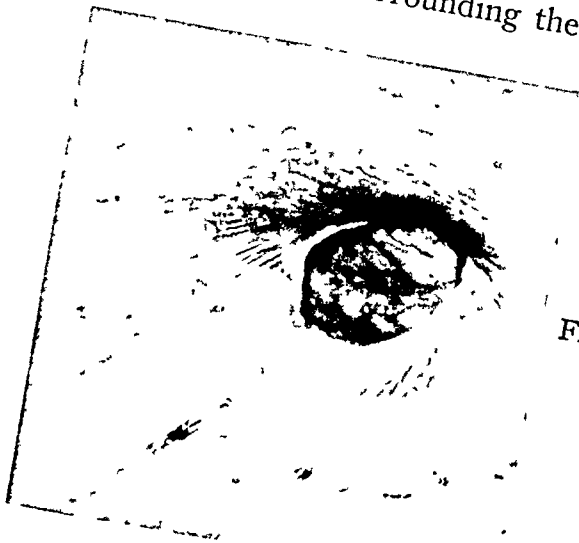


FIG. 2-A

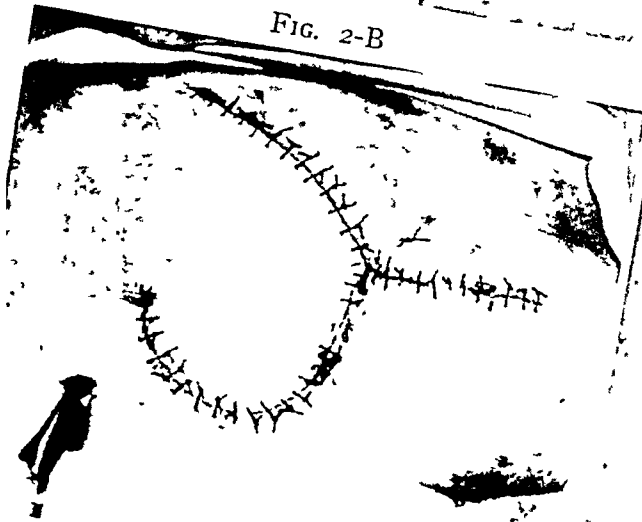


FIG. 2-B



FIG. 2-C

FIG. 2—(A) Preoperative trochanteric ulcer.  
FIG. 2—(B) Ulcer at time of operation  
FIG. 2—(C) Two months postoperative.

for several inches in all directions in a normal cleavage plane so that the edges of the defect could be brought together without undue tension. At this time, a stab wound is made at the periphery of the undermined area and a small flat rubber drain is inserted down to the base of the former ulcer. The deep tissues are then closed with multiple, interrupted sutures of No. 00 chromic catgut and the skin edges closed with multiple interrupted sutures of No. 000 silk. A layer of white gauze is applied, followed by a large pressure dressing of mechanic's waste. It was observed that when pressure dressings were not used, sinus formation was frequent beneath the closure.

In dealing with the large ulcers of the trochanteric area, the method of rotation flap was used. It was early recognized that the movement of the greater trochanter caused a constant tearing and sinus formation in the region of the ulcer and contributed largely to the wide undermining process which is common with this type of ulcer. For this reason, during the operation, the patient's legs are carefully padded and bound together in such a manner that the leg on the side opposite to the ulcer in question acts as a splint to prevent rotation of the trochanter under the area. All of the scar tissue surrounding the ulcer is excised down to normal tissue. A pattern is then made of the defect with a



FIG. 3.—Grafted sacral ulcer nine months postoperative.

piece of oiled silk and this pattern transferred to an area adjacent to the ulcer. It has been observed that flaps taken from an area ventral to the ulcer are preferable, because in several dorsally acquired flaps, circulation became jeopardized as the result of skin stretching when the thigh was flexed. The area surrounding the ulcer is now undermined for a distance of several inches and bleeding carefully controlled. The flap is outlined and raised on a normal cleavage plane of the thigh. This entire area is then undermined and bleeding controlled. A stab wound is made in a dependent portion of the undermined area and the flap sutured in place with multiple interrupted subcutaneous sutures of No. 00 chromic catgut. It has been our experience that with adequate undermining the donor area could usually be closed without undue

tension. However, in a number of cases, the donor defect was so large that a split-thickness skin graft was required to close a portion of the donor area. The skin edges are then closed with multiple interrupted sutures of No. 000 silk and a rubber drain placed in the stab wound to reach the base of the previous ulcer. It should be noted that in none of the cases was the drain placed through the line of suture. This was considered important, because the area along the suture line is usually somewhat scarred and the line of greatest tension exists at this point. The area of the suture line is the area of previous abnormality and carries the added danger of potential infection. The healing of the stab wound has occurred readily following removal of the drain. Oint-

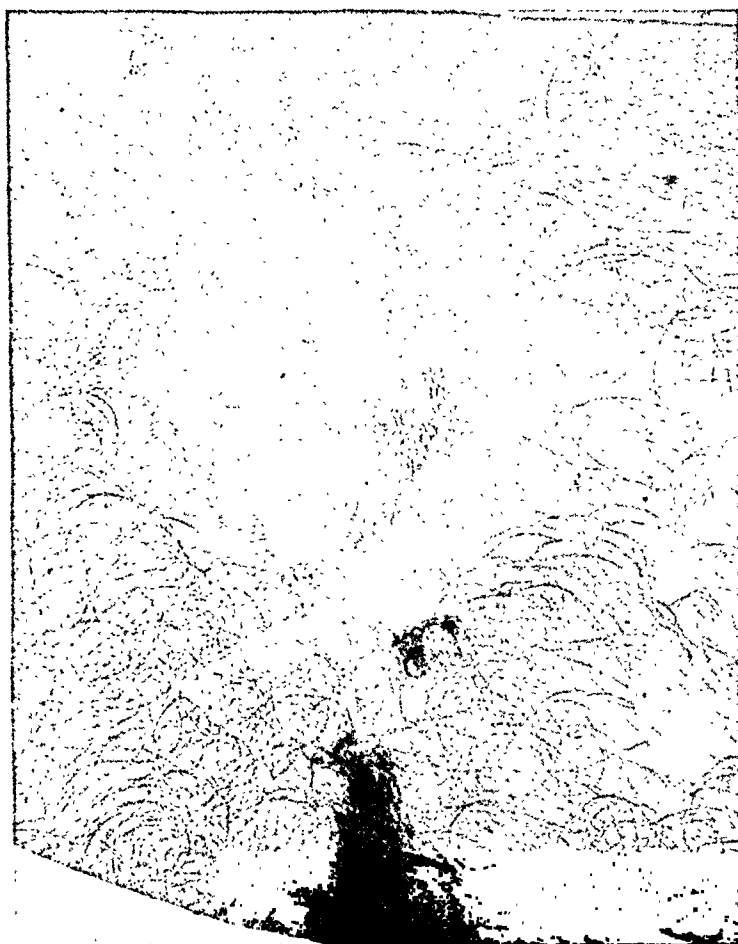


FIG. 4.—Grafted sacral ulcer ten months postoperative.

ment gauze dressing is applied, followed with pressure dressing of sterile mechanic's waste. Following closure of this particular type of ulcer by this technic it is deemed important that a large amount of adhesive tape be applied to prevent undue tension on the suture line by taking up skin slack. It must be remembered that in this group of patients, most without pain sensation, the normal protective mechanism has been lost.

The technic in skin grafting of the large ulcers is as follows: After the ulcer has been débrided down to a fair base, bleeding is controlled with hot saline packs. In a number of cases, local adrenalin has been employed to aid in hemostasis. The grafts are usually taken from the posterior portion of the

thigh, and are of approximately 12/1,000-inch in thickness. Before the graft is placed into position, the granulating area is sprinkled with sulfanilamide crystals. The graft is now laid into position and sutured with a continuous stitch of No. 000 silk around the periphery of the ulcer. Perforation of the graft with multiple small holes allows drainage of serum from beneath the graft. Ointment gauze is applied followed by a pressure dressing with mechanic's waste. This step is considered important to prevent collection of serum or an hematoma underneath the graft. It has been our experience that no difficulties have arisen in healing of the donor area in any of our cases. This is probably due to the fact that the donor skin is acquired from over a fleshy portion of the body which is subjected neither to periods of local ischemia from pressure nor to excessive moisture.

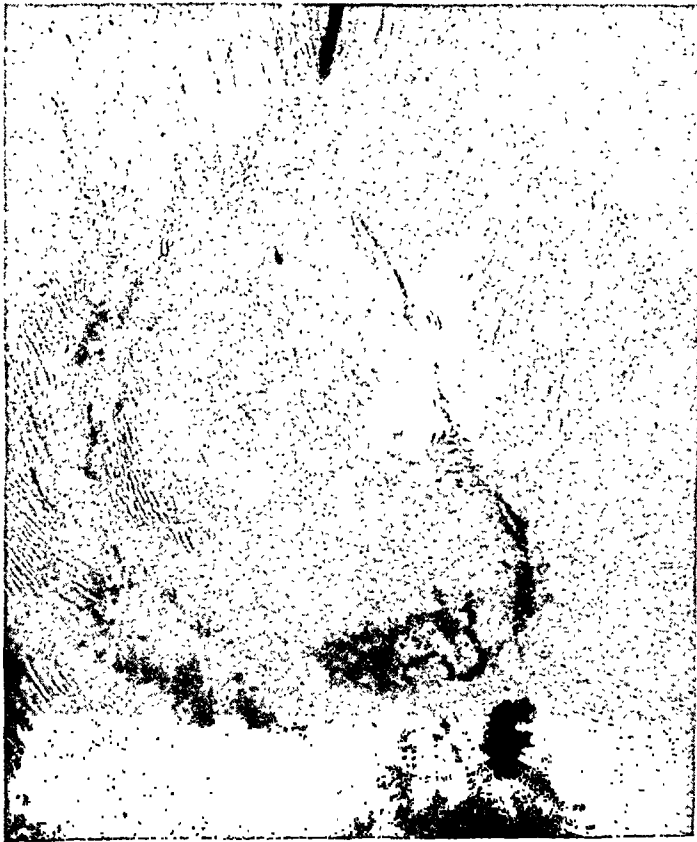


FIG. 5.—Grafted sacral ulcer two months postoperative.

#### POSTOPERATIVE CARE

The postoperative care of small ulcers, both in the trochanteric and sacral regions, has presented no particular problem. A standard postoperative treatment is being employed in all cases. On the third day postoperatively, the dressings are removed and the area of closure or graft is cleaned with hydrogen peroxide to remove the serous discharge. The area is dried with ether and sulfanilamide powder dusted along the line of closure. A dry pressure dressing of mechanic's waste is then applied. Hereafter, this procedure is done daily

using the same technic, until on the tenth or twelfth day the sutures are removed. At one time in our experiences, ointment dressings were applied following the removal of the original dressing. It was discovered, however, that ointment dressings over a period of several days resulted in maceration at the suture line. The drain is partially pulled out on the third day and totally removed on the fifth day in those cases in which a drain had been employed. There is a considerable amount of serous discharge for the first five days, which is gradually decreased until on the eighth day it should be minimal. The cases in this series received parenteral penicillin for several days postoperatively.

Early in our experience, wet dressings were applied immediately postoperatively in the skin graft cases. This was found to be inadvisable because of maceration of the graft resulting in loss of parts of the graft.

There has been little or no tendency for these surgically closed ulcers to break down. Most cases in the series have been kept under observation for a year and each patient is instructed in the care of his healed graft or closure. The same factors responsible for the occurrence of a decubital ulcer would contribute to recurrence or break-down. These factors are prolonged pressure with resulting local ischemia, excessive moisture and general debility. Training this type of patient to frequently change his position is not difficult, particularly as he is most interested in not having his ulcer recur. We have observed that following successful closure of a large ulcer, the patient's appetite increases and with this increased appetite a sense of well-being occurs. Serum proteins rise and on several occasions negative albumin-globulin ratios have become positive. These phenomena occur too quickly following closure to be considered unrelated to the closure. Local care of the healed closure or graft consists of daily massage with a light oil containing lanolin, frequent position changes and careful avoidance of prolonged contact with body excretions.

DISCUSSION.—The operative results in a series of 70 cases of decubital ulcers have been observed over a period of 12 months and, on the whole, have been satisfactory. Thirty-two ulcers were small in type and were closed by excision and suture. Twenty-eight healed *per primam* and there were four failures. One of these has been reoperated and has healed. Another healed by epithelization. The final results of the remaining two are unknown as the procedures were performed at another hospital.

Nineteen rotation flaps were performed and there were no complete failures. In several cases, a superficial separation of the suture line occurred in a small area which readily healed by secondary intention.

Nineteen skin grafts to large sacral ulcers were performed and 11 healed *per primam*. Six healed partially, and two were total failures. Of the six partially healed grafts, two were reoperated successfully. It is our opinion that a partial take is followed by more rapid epithelization than would occur in a surgically untreated ulcer. This has been observed in those remaining cases classified as total failures.



## CONCLUSIONS

Decubital ulcers in paralyzed patients have been treated with primary closure, rotation flaps and split-thickness skin grafts. Donor sites heal readily in those cases in which skin grafts are employed. The closure of a large decubital ulcer is related to an increase in appetite and sense of well-being in the patient. In addition several months of nursing care to a slowing granulating and epithelizing area are avoided. End-results after one year's observation have been satisfactory and the tendency to break-down or recurrence has been minimal in this series.

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DISCUSSION.—DR. JOSEPH E. J. KING, New York, N. Y.: This most remarkable work done by the young medical officers of the Service and presented to us tonight is truly epoch-making.

At Ashford General Hospital yesterday the young Captain who showed us the paraplegias appeared to be so kindly disposed to his patients, so cordial and encouraging, and he tried to make the boys feel as happy as possible; I was deeply impressed by his attitude. Then we were rather surprised and very much pleased to see the splendid work which had been accomplished in the curing of bedsores, *i.e.*, the skin grafts and flaps.

In our service during the last War most of the paraplegias resulting from gunshot wounds slowly died of an ascending infection after lingering on the wards for a considerable period of time. It goes without saying we did not have the advantage of the new drugs and Munro's tidal drainage was unknown. Treatment of paraplegias has vastly improved at the present time. Even so, many of these young men will be invalids for life and will be unable to marry and have children. They do not present the hopefulness shown by most of the other wounded men, although they may be amputees, or may have sustained other serious or disabling injuries of the chest, abdomen, peripheral nerves, *etc.* This latter group may go home in good fettle and happy, and continue so through life. It is my belief that the paraplegias, for the most part, will not be able to do this; many of them will sit or lie around in invalid state.

After the last War I was connected with the Veterans Bureau for about 13 years and, in a number of instances, have seen the men's compensation cut down from \$150 per month to as little as \$8 a month in claimants who had not improved in the interval. I feel that an especial effort should be made on our part to see that this particular group of patients receives full and just compensation for their injuries. At the present time our government is spending a great sum of money for all sorts of things, and I know of no better use to which to put it than for the care and welfare of these unfortunate soldiers.

COL. R. GLEN SPURLING, Washington, D. C.: I feel that I should say a few words about the program for the future being planned for these patients. I am sorry that

General Rankin and Colonel Woodhall could not have been here to speak, for they have played such a vital part in planning it.

Many of these patients are going to require hospitalization for years to come. Others are soon going to find their niche in a civilian economy, quite independent of any Army or Veterans hospital care. The beautiful demonstration of professional achievement you have heard here today is but one part of the program. I wish that you might have seen the tremendous strides that have been made in rehabilitating them from bed invalids to a useful ambulatory status. The transition from a bed to a wheelchair existence is not enough; they actually walk, learn productive vocations and cultural avocations. They even learn to drive automobiles quite independently. They are going to do a lot of things that will make life worth while.

Many of the complete lesions are going to continue to be Veterans Administration problems once they have received maximum benefit in Army hospital installations. Looking forward to this, we have plans for setting up four or five Paraplegic Centers to carry on this work of rehabilitation. In fact, if the present plan fully materializes, the Veterans Administration hopes to take over five Army hospitals, into which these patients have been concentrated, so that there will be a minimum amount of disruption of the training program. It is General Hawley's plan to give them everything Doctor King wants them to have; every modern educational and occupational aid to make them a happy group of people.

DR. WALTER C. G. KIRCHNER, St. Louis, Mo.: Relative to the papers presented, I would like to show similar problems as they occur in civilian life, and how the handling of some of the lesions might also apply to cases in Army practice.

This first slide represents a roentgenogram which shows a pronounced dislocation and fracture of the lumbar vertebrae, and the second slide, the result after three weeks, traction having been applied, and it will be noticed that an improvement has taken place in the alinement of the vertebrae.

In the third slide are seen extensive decubitus lesions in a case of spinal cord damage.

An important factor in the treatment of spinal cord injuries in the home is the use of a proper type of bed and a suitable Balkan frame, as illustrated in the next slide. In addition to a means for elevation of the trunk and lower extremities, provision is also made for the lowering of the midportion of the bed to enable an easier use of the bedpan. The bed is independent of the Balkan frame. Even in the home, after instructing the wife of the patient, satisfactory care of the bladder and bowels may be had when a proper type of bed is installed.

I have found the use of the plaster shell a valuable aid in the treatment of injuries of the spine. While offering protection and the ability of more easily handling the patient, it adds to his comfort, and it is a means of preventing and also of curing bedsores. The slide shows the shell in position, which also permits treatment of bedsores.

The satisfactory treatment of bedsores is based upon the principles of wound healing. Careful studies have shown that healing takes place not only by an advancing of the epithelium, but also the entire thickness of the skin advances in an effort to close the wound, when the gaping is not too large. There are two forces at play, centrifugal and centripetal, the one causing the wound to enlarge, the other encouraging closure. When the force which aims at closure is greater than the centripetal force there is a tendency on the part of nature to promote healing. Taking advantage of nature's method of healing the wound, closure of the bedsore is promoted by the use of adhesive strips, so applied that by stretching of the skin, approximation of the edges is encouraged. At intervals of several days the strips are reapplied, one at a time, and it is surprising to notice that large bedsores are made to heal with but a small residual scar which, by means of massage, may be made free and mobile. The slide shows the result of healing of a bedsore large enough to expose the rectum.

In the home, the wife often makes a most satisfactory nurse, and I have under my care a case of complete paraplegia, in which, with the aid of the wife, attention to the bowel and catheterization has been performed for a period of more than 23 years, and in spite of this great handicap the patient has learned a trade and is self-sustaining.

ADMIRAL W. M. CRAIG, Bethesda, Maryland: This has been a very stimulating symposium and I want to congratulate the essayists on their presentation. The Navy program

in the treatment of these cases has been very similar in that they have been more or less concentrated in the Centers where they could receive the combined care of the neurosurgeon, orthopedist, the urologist and the physical therapist and vocational therapist. I can add my hearty and sincere second to the remarks made by Doctor Gage regarding these cases, in that their rehabilitation has been one of the outstanding medical contributions of this War. These veterans suffering from spinal cord injuries resulting in permanent loss of motor and sensory function, as well as bladder and bowel dysfunction, are far better off than were the veterans of the last War and the civilians who were treated in the prewar years.

The Navy has been interested in improving the condition of the bladders of these cases by instituting transurethral section of the internal sphincter. This has been done in certain cases where there was difficulty in emptying the bladder, resulting in retention or the presence of marked residual urine. While insufficient time has elapsed to evaluate the permanent results, yet the cases we have had at the National Naval Medical Center have shown most gratifying results. A much larger series of cases has been done on the West Coast and the reports we have had are most encouraging and we can hope that this procedure will add to the program of rehabilitation of these cases as presented at this meeting.

DR. EDWARD H. RAY, Lexington, Ky.: I had the fortunate experience of visiting Newton D. Baker General Hospital a few months ago and of seeing the beautiful work being done there. I also had the chance of observing the paraplegia wards at Nichols General Hospital, where I was in charge of the Urologic Section for three or four months, and the contrast between the general condition of the patients at the former, where streptomycin was being used, and that of those at the latter where no streptomycin had been available, was great. Without streptomycin the morbidity from urinary tract infections and from renal calculi was marked. Shortly before leaving the service I received a supply of streptomycin and found it to be just as valuable as has been indicated by Major Petroff.

Admiral Craig has mentioned the bladder neck obstruction that occurs in many of these patients and the fact that transurethral resection affords relief in many instances. It has been very interesting to study this condition in such a large group of patients. With a complete lesion of the spinal cord an automatic type of bladder usually develops, so that it is able to empty itself with varying degrees of completeness.

There is no true internal urethral sphincter, but there is a pseudosphincter formed by fibers of the detrusor muscle which extend in swirl-like fashion into the posterior urethra. The effort made by the automatic bladder to empty itself results in an hypertrophy, not only of the detrusor proper, but of the muscle fibers at the vesical orifice, so that in time a bladder neck obstruction develops with increasing urinary retention. This bar or collar-shaped obstruction lends itself readily to transurethral resection in carefully selected cases, as determined by cystoscopic examination.

I should like to congratulate the essayists on their presentation of this interesting subject. I enjoyed their papers very much.

COL. DAVID H. POER, Martinsburg, W. Va. (closing): I want to thank everyone for their discussion, and I have little to add. We have discussed in detail with you the treatment carried out in Phase II. I had hoped Colonel Spurling would discuss in more detail the treatment of those patients in Phase I, because it seems to me that lowering of the mortality from 50 to 60 per cent in previous wars to 12 per cent in the present war in that phase is particularly noteworthy, and we need to know more of the details; it represents an outstanding accomplishment of the neurologic surgeons.

Phase III definitely presents a challenge and I do not feel that we have answered it. I am not sure that all the plans discussed by Doctor King and others are the right approach. If these patients could only forget their pension, saving it for health insurance that they cannot buy, and develop the idea that they can become self-supporting again, then they are more likely to coöperate and work with you in learning to get about and perfect a trade. It requires a lot of fortitude to do what they must do, and if they need the stimulus of wanting and needing and desiring to support themselves and their families, it is something that apparently can be provided in no other way. We are bound to see individuals who, knowing they have a liberal government check coming in, will have

a tendency to lag, and this is difficult to overcome. I wonder in my own mind if we could not let that government money accumulate for emergencies in the future, and make these men get out and learn to walk and get about, and make a living.

To the orthopedic surgeon particularly, loss of motion in the lower limbs presents a challenge. Already some work has been done in Baker Hospital in tendon transplants and stabilization of joints, and I think the orthopedic surgeons can help considerably in enabling these individuals to get about.

MAJOR BORIS P. PETROFF, Martinsburg, W. Va. (closing): The desirable urologic end-result in paraplegics is to dispense with all artificial aids in emptying the bladder, such as suprapubic cystostomies and urethral indwelling catheters. These are avenues of infection which cause unnecessary complications in the urinary tract. Forty patients came to us with suprapubic cystostomies in October, 1944, and by July, 1945, all suprapubic cystostomies had been closed and urethral catheters instituted with tidal drainage according to the method of Dr. Donald Munro. Now 25 out of the 40 are voiding without residual. The remaining 15 with indwelling catheters have not been able to start the urinary stream because of bladder neck obstruction or bladder atony. Five of these have had transurethral resections of the bladder neck and are now voiding without residual. Only a small amount of tissue had to be removed from the ridge of fibrous tissue which had formed between the verumontanum and bladder. Ten patients remaining with urethral catheters will void after their bladder necks are resected, too.

Streptomycin is very important in transurethral resections in paraplegics. If given prior to resection as well as afterward, the possibilities of complications due to overwhelming infection with gram-negative bacilli are greatly reduced, and a smooth recovery is assured.

# BATTLE INJURIES OF THE ARTERIES IN WORLD WAR II\*

AN ANALYSIS OF 2,471 CASES

COLONEL MICHAEL E. DEBAKEY, M.C.,

AND

LT. COLONEL FIORINDO A. SIMEONE, M.C.

ACUTE INJURIES OF MAJOR ARTERIES, which literally threaten both life and limb, have always constituted a serious problem in the surgical management of traumatic conditions. In times of war, this subject assumes even greater significance, and further impetus is, therefore, provided for the study of the problem and the development of a more effective solution. Although considerable progress was made in this field of surgical endeavor in the interval between World War I and World War II, early experience in the latter conflict soon showed that satisfactory methods of managing arterial injuries were yet to be developed. Moreover, there was little unanimity of opinion concerning either concepts of management or procedures of choice in individual cases. As experience increased and as various technics were tested, increasing difficulty was met in their evaluation because there were no accurate figures on survival expectancy after acute ligation of arteries under war-time conditions. For these reasons, special efforts were made in certain active Theaters of War to study the problem intensively and to collect data which would permit analysis and would provide more definitive information concerning it.

In this report an effort has been made to present as accurately as possible, on the basis of data now at hand, information as to war wounds of the arteries occurring in American Forces during World War II, with respect to incidence, types, location, morbidity, methods of management, and factors influencing the outcome. These data have been obtained from all sources available to the Surgeon General's Office, including special reports from consultants, hospitals and field units, as well as from individual medical officers who have made special studies of arterial wounds. Comparisons of significant data, methods and concepts have been made with those of previous wars whenever it seemed pertinent or desirable.

It should be clearly understood that the data derived from the 2,471 arterial wounds on which this analysis is based pertain only to fresh or acute wounds and not to later and more chronic types of complications, such as traumatic false aneurysm (including the so-called pulsating hematoma) and arterio-venous aneurysm. It is most important to bear this in mind, for much confusion has arisen in the past from failure to define clearly the type and character of the data reported and from the inclusion of acute and chronic lesions in the same reported series.

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\* Read before the Fifty-seventh Annual Session of the Southern Surgical Association, December 4-6, 1945, Hot Springs, Virginia.

INCIDENCE

A search of the literature reveals little information concerning the incidence of wounds of the arteries among battle casualties in previous wars. Generally, the statistics which are available would seem to underestimate the incidence of this type of wound. Even in World War II, when a real effort was made to report the figures accurately, the data are still deficient in certain respects. The lack of information is not difficult to explain: For obvious reasons vascular injury is seldom recorded as a primary diagnosis, and in many instances, including both the most serious and the least serious cases, it is probably not

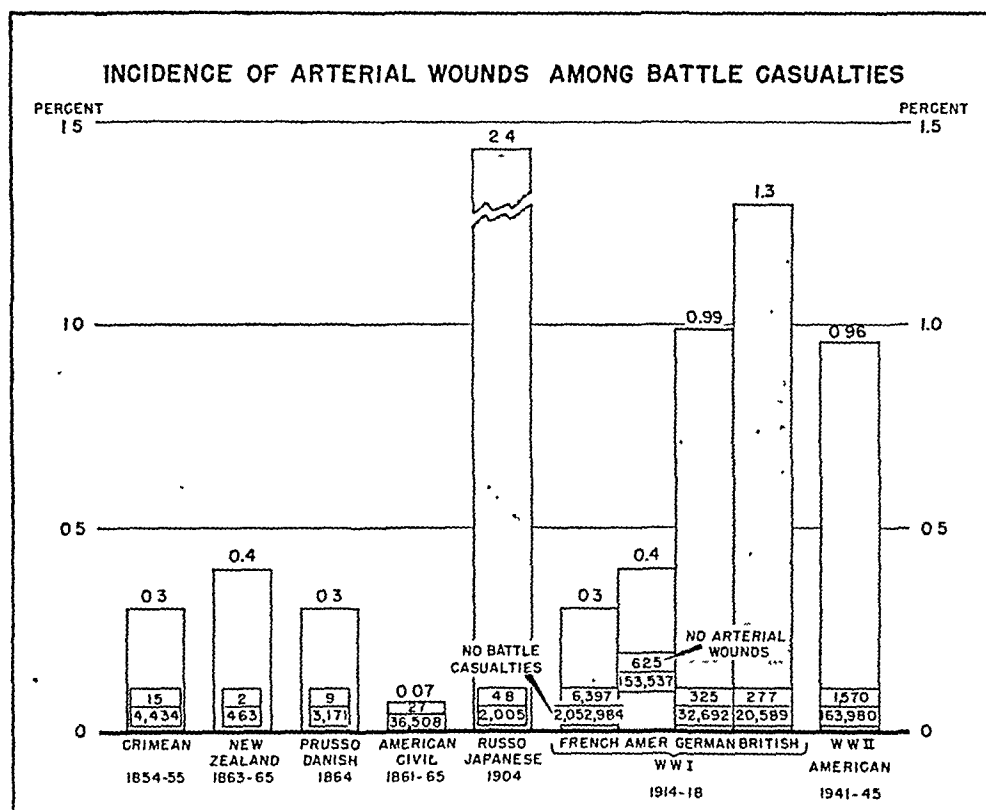


CHART 1.—Incidence of arterial wounds among battle casualties in various wars.

recorded at all. In addition, analysis of the available statistics requires considerable caution. Most series are actually or relatively small, and many from previous wars include both acute and nonacute conditions. In drawing conclusions from them, therefore, many qualifying circumstances must be taken into account.

All available statistics (Chart 1) suggest that the incidence of arterial wounds among battle casualties in previous wars was extremely low, ranging from 0.07 per cent in the War Between the States to 2.4 per cent in the Russo-Japanese War.<sup>24, 63, 119, 120, 122, 143, 162</sup> LaGarde reported an incidence of 0.8 per cent in 1,400 casualties at Santiago during the Spanish-American War.

From data tabulated in the official American history of World War I the incidence of vascular wounds among American troops has been computed to be 0.4 per cent (Chart 1).<sup>120</sup> The British official history,<sup>129</sup> although it devotes considerable space to the subject of arterial wounds, supplies no data concern-

ing incidence, and Makins' classic monograph<sup>128</sup> on gunshot injuries of the blood vessels says nothing on this point. His material, as a matter of fact, is limited to 1,191 cases (Table I) made up of two series; one consists of 668 cases handled by numerous individual surgeons in the British Isles and over-

TABLE I

BRITISH WORLD WAR I (MAKINA*)					AMERICAN WORLD WAR II				
	Total No.	%	Loss of Limb†		Total No.	%	Loss of Limb		
			No. Cases	Per Cent			No. Cases	Per Cent	
Aorta.....	5	0.4	5	100.0	3	0.12	2	66.6	
Carotid.....	128	10.7	38	29.6	10	0.4	3	30.0	
External carotid....					3	0.12	0	00.0	
Renal.....					2	0.10	2	100.0	
Vertebral.....	3	0.2	0						
Subclavian.....	45	3.7	4	8.8	21	0.85	6	28.6	
Axillary.....	108	9.0	5	4.6	74	0.30	32	43.2	
Brachial total.....	200	16.7	12	6.0	601	24.3	159	26.5	
Above profunda..					97	3.9	54	55.7	
Below profunda..					209	8.5	54	25.8	
Radial-ulnar.....	59	4.9	3	5.0					
Radial.....					99	4.0	5	5.1	
Ulnar.....					69	2.8	1	1.5	
Radial and ulnar...					28	1.1	11	39.3	
Common iliac.....	1	0.1	1	100.0	13	0.5	7	53.8	
External iliac.....	4	0.3	0	0	30	1.2	14	46.7	
Internal iliac.....	1	0.1			1	0.05	0	00.0	
Femoral total.....	366	30.5	74	20.2	517	20.9	275	53.2	
Above profunda..					106	4.3	86	81.1	
Below profunda..					177	7.2	97	54.8	
Profunda.....					27	1.1	0	00.0	
Popliteal.....	144	12.0	62	43.1	502	20.3	364	72.5	
Anterior tibial.....	26	2.2	1	3.8	129	5.2	11	8.5	
Posterior tibial....	97	8.1	9	9.2	265	10.7	36	13.6	
Ant. and post. tibial	7	0.6	2	28.6	91	3.7	63	69.2	
Peroneal.....	4	0.3	2	50.0	7	0.28	1	14.3	
Ant. tibial and peroneal.....	3	0.2	0	0					
Post. tibial and peroneal.....	1	0.1	0	0	5	0.20	2	40.0	
Both tibials and peroneals.....					1	0.05	1	100.0	
Total.....	1202‡		218	18.1	2471		995	40.3	

\* The figures compiled from Makins' tables represent combinations of the totals for "gangrene" and "amputations," so that the maximum number was obtained without possible duplications. The numbers represent the minimum number of cases that must have had amputations.

† In case of aorta, carotids, and renal arteries, the figures indicate the numbers that died or developed cerebral complications.

‡ This total differs from the number of 1,191 cases given in Makins' master table, because 11 vessels of the leg were added from a detailed table presented in the text.

seas, and the other of 523 cases similarly handled in France but supervised by a single surgeon. Only modified reliance, Makins warned, could be placed on any deductions drawn from this material, and it contributes nothing to the incidence of vascular wounds among British troops in World War I. The only material available on that subject was found in Bowlby and Wallace's report of 20,589 casualties treated at a single casualty clearing station, 277 of whom (1.3 per cent) required ligation of major arteries.

Maurer<sup>135</sup> recorded 443 wounds of the blood vessels observed among 8,000 wounded treated in a French ambulance service. If the 17 per cent of wounds involving only the veins be excluded, the incidence of arterial injuries is 4.6 per cent. Figures reported by Mignon (so stated that a tabulation was possible) for six French ambulances show 399 vascular injuries (2.02 per cent) among 19,734 wounded. The French official history of World War I<sup>143</sup> shows 6,397 vascular injuries (0.99 per cent) among 2,052,984 wounded. The German incidence, according to Franz, was 0.99 per cent.

Matas,<sup>132</sup> in his exhaustive consideration of vascular injuries, stated that in World War I, 24.7 per cent of battle casualties at the front required treatment for injuries of the blood vessels and added that 2 per cent of all wounded admitted to Base Hospitals presented traumatic aneurysms. These are the highest figures that have been found in the literature for the incidence of vascular injuries among battle casualties, and the source material upon which they were based was not indicated.

TABLE II  
CAUSES OF AMPUTATION IN 189 CASES OF VASCULAR INJURY\*

	1943		1944-45		1943-45	
	Cases	Per Cent	Cases	Per Cent	Cases	Per Cent
Primary . . . . .			43	32.3	43	22.8
Gangrene . . . . .	47	84.0	64	48.1	111	58.7
Clostridial myositis . . .	8	14.0	13	9.8	21	11.1
Other infections . . . .	1	2.0	13	9.8	14	7.4
Total . . . . .	56	100.0	133	100.0	189	100.0

\* Amputations done at initial wound surgery, when vascular injury made survival of limb unlikely.

*World War II.*—Considerably more data on which to base estimates of the incidence of vascular injuries among battle casualties are available for World War II. Moore stated that the 13 vascular injuries which he treated in a German prison camp formed 0.43 per cent of all hospital admissions. All the patients were seen late (between three and 42 days after wounding) and the circumstances necessarily made the group highly selective. Cole and Neel found nine injuries of major vessels (1.4 per cent) among 638 wounds of the extremities sustained in amphibious warfare in the Pacific.

At the present writing, reasonably complete data are available from armies in three of the most active American Theaters of Operation in different parts of the world. The total incidence of 0.96 per cent (1,570 vascular injuries among 163,980 battle casualties) is remarkably close to the incidences reported from the separate Theaters and armies (Chart 2). The similar correspondence noted in the distribution of vascular wounds among wounds of the extremities observed in the separate Theaters and armies suggests that the over-all incidence of 1.4 per cent is fairly representative (Chart 3).

*Incidence in Relation to Amputation.*—The total incidence of vascular wounds among all casualties, and even among wounds of the extremities, is both relatively and absolutely small, and even the large numbers of wounded in World War II do not make the total number of vascular wounds very large.



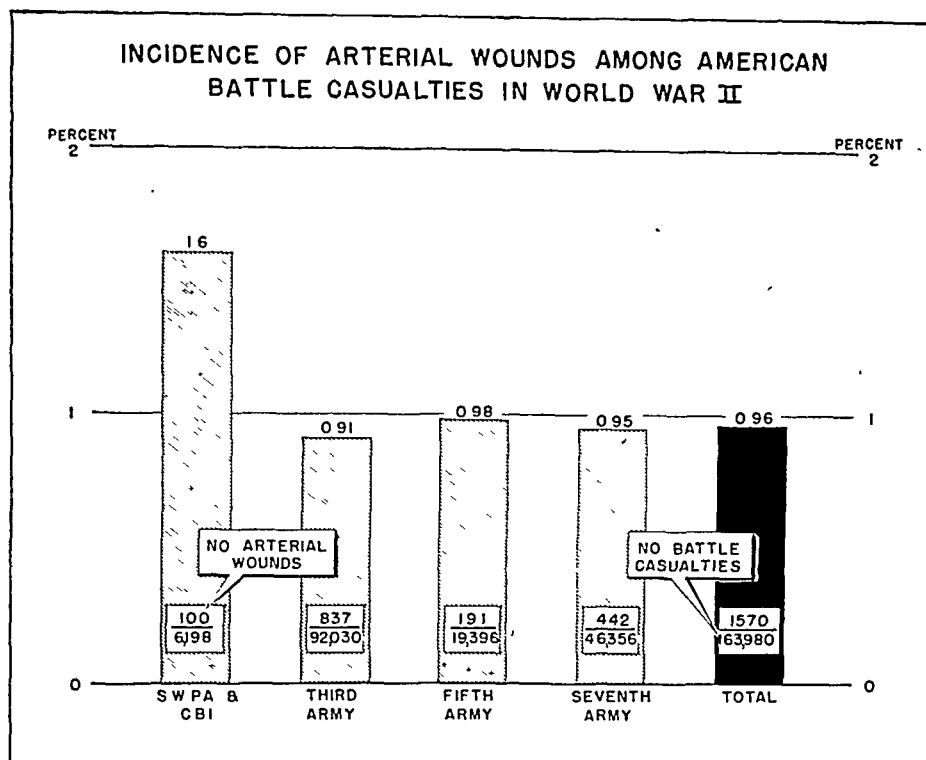


CHART 2.—Incidence of arterial wounds among American battle casualties in World War II.

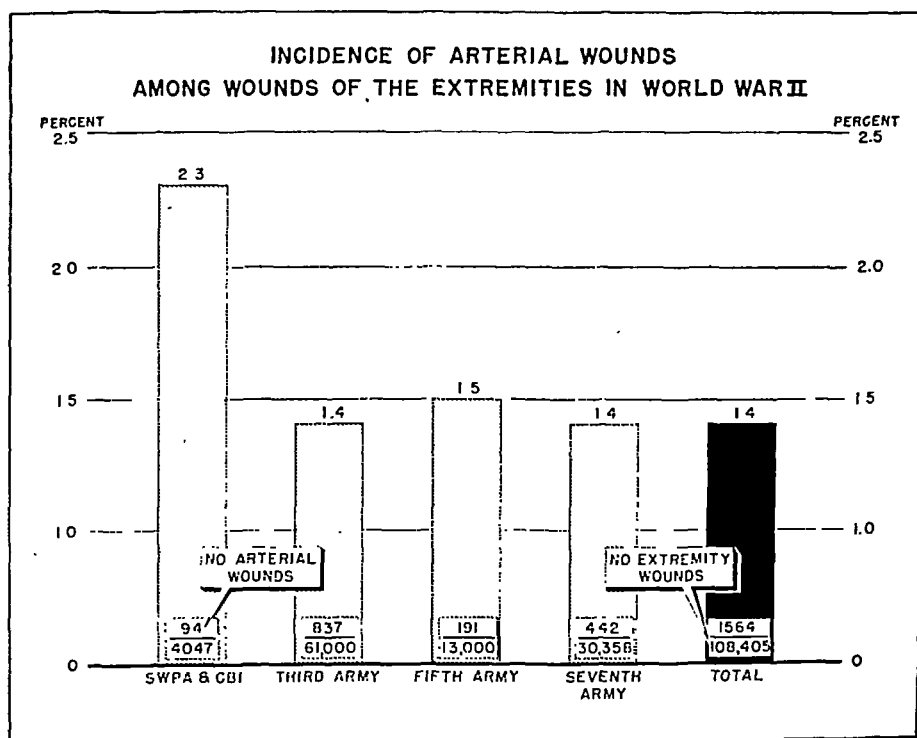


CHART 3.—Incidence of arterial wounds among wounds of the extremities in American battle casualties in World War II.

The real significance of these injuries, however, is better appreciated by examining the frequency with which they appear as a cause for amputation.

No significant statistics compiled from this point of view have been found in the literature, but accurate data are available from the Mediterranean and European Theaters of Operation (Chart 4). Among 3,177 major amputations from these Theaters, 2,179 (68.6 per cent) were the result of extensive trauma, 380 (11.9 per cent) were the result of clostridial myositis or other serious infections, and 618 (19.5 per cent) were the result of major arterial injuries. Figures which became available with the capture of a German amputation Center showed that among 1,359 major amputations, 64.3 per cent were the

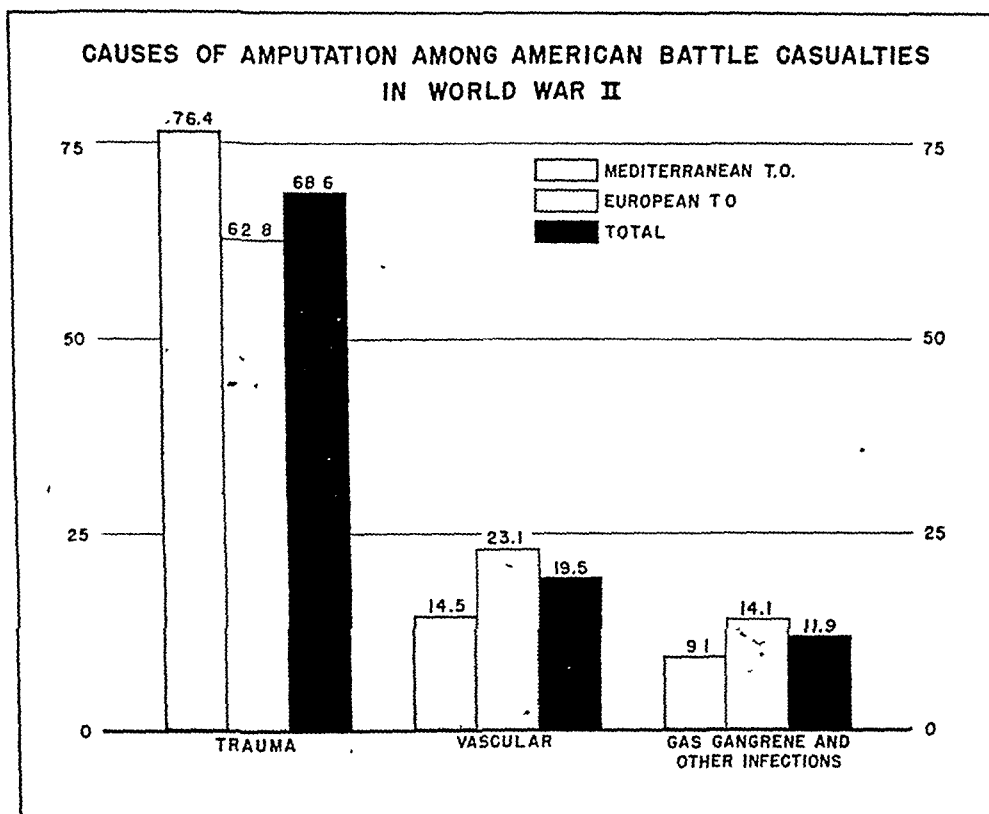


CHART 4.—Causes of amputation among American battle casualties in World War II.

result of trauma, which is close to the American incidence of 68.6 per cent. Only 6 per cent, however, were the result of vascular injuries, while 29.7 per cent were the result of clostridial myositis. Corresponding figures on the Russian experience have been reported by Kramarov, who observed that trauma was the cause for amputation in 16 per cent of the cases, vascular injury in 5 per cent, and gas gangrene and other infections in 79 per cent. The far smaller incidence of the latter in the American statistics is a reflection of the highly creditable standards of surgery achieved by American surgeons in Forward Areas.

The figures which have been presented in this section provide a much better perspective of the vascular problem in war surgery than has previously been possible. For one thing, they provide a true concept of the magnitude of the

problem. For another, they make clear that the great majority of amputations are inevitable and beyond the surgeon's control. Therapeutic measures designed to save the limb are clearly applicable, at best, to not more than 20 to 25 per cent of all such injuries, which should put to rest the overenthusiastic and even extravagant claims occasionally made as to the possibilities of salvage of limbs in battle wounds of the blood vessels.

*Regional Distribution of Vascular Injuries.*—An analysis of the relative frequency with which various arteries are involved in battle casualties (Chart 5, Table I) shows that the brachial, tibial, femoral and popliteal arteries are involved far more frequently than any others. They accounted for 70 per cent of the total vascular injuries reported by Makins and for 85 per cent of the vascular injuries sustained by American troops in certain Theaters of Oper-

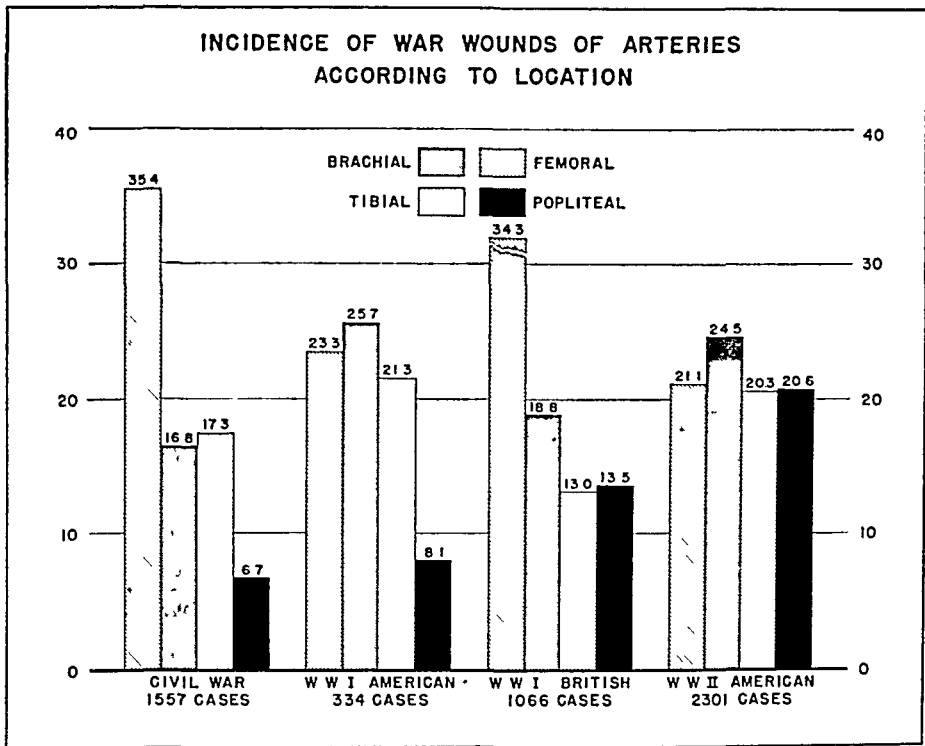


CHART 5.—Distribution according to site of arterial wounds of the extremities in various wars. These incidences, it should be emphasized, are based only on arterial wounds of the extremities, whereas those shown in Table I are based upon all arterial wounds.

ation in World War II. The explanation of this preponderance is simple: Casualties suffering from injuries of larger arteries frequently do not live long enough to reach medical installations (and, therefore, do not appear under precise diagnoses in medical statistics), while injuries of less critical arteries are frequently not discovered at all, or, if discovered, are not recorded.

A comparison of the incidences of wounds of the brachial, tibial, femoral and popliteal arteries in the War Between the States, World War I (British and American statistics) and World War II (American statistics) shows a relatively close order of magnitude of the incidences of wounds of these four

arteries in World War II as compared with earlier wars, and a much higher incidence of popliteal injuries in the recently terminated war as compared with previous wars. The explanation for these differences can be only conjectural. It may lie in more exact methods of recording, in a greater and more selective interest in vascular injuries, and perhaps in the more conservative surgical policies directed toward conservation of limbs in World War II.

THE THERAPY OF VASCULAR INJURIES  
GENERAL CONSIDERATIONS

Any discussion of the therapy of vascular injuries must begin with the premise that the restoration of the flow of blood through the original channel is the desideratum. Unfortunately, even in civilian traumatic surgery, this can be accomplished in only a limited number of cases, while in military surgery

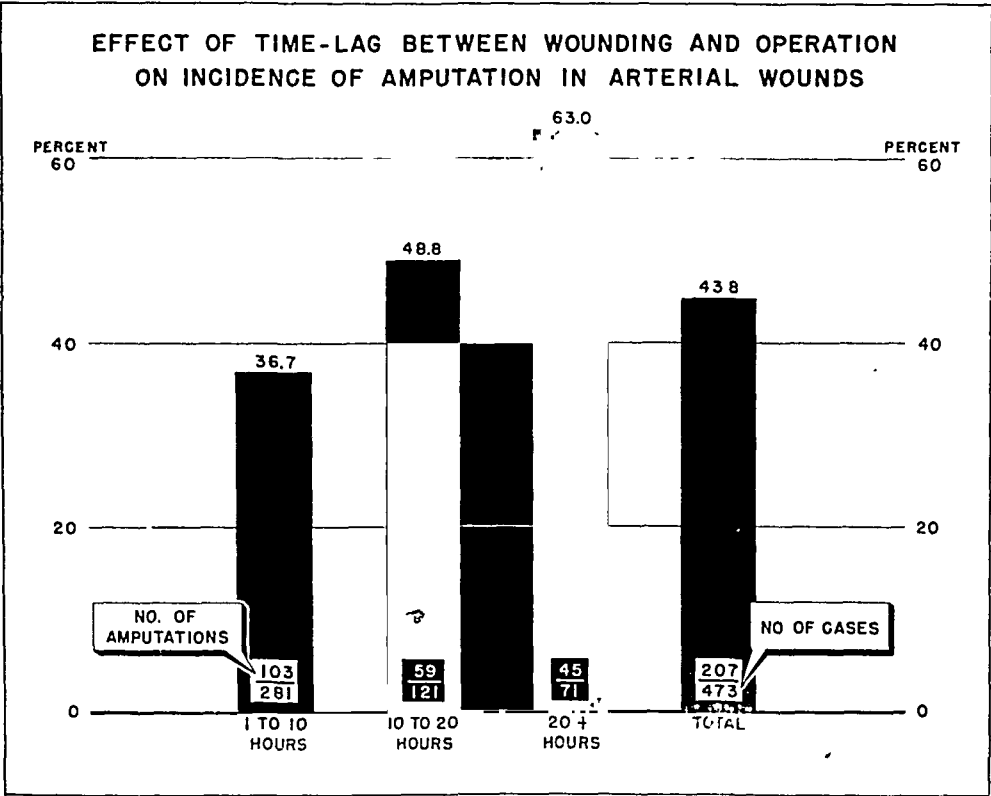


CHART 6.—Effect of time-lag between wounding and operation on incidence of amputation in arterial wounds of the extremities among American battle casualties in World War II.

the number is even more limited for certain definite reasons enumerated below. Essentially, these reasons may be divided into two categories: (1) Those in which the factors are of such vital significance that they seal the fate of the limb regardless of any form of therapy; and (2) those which jeopardize the effects of ideal therapy or preclude its institution.

*Time-Lag.*—Ideal therapy, designed to reestablish the circulation of the limb, must be done within a limited period of time after wounding. The general (arbitrarily set) limit is six to eight hours. The time-lag in military surgery, however, is predominantly a military matter. Even under the happiest

circumstances the time-lapse between wounding and treatment in the majority of injuries averages over 12 hours.\* After such a lapse of time, regardless of the nature of the original wound, thrombosis has probably occurred in the vascular tree distal to the injury and the tissues of the wounded extremity have been deprived of oxygen and nutrition too long a time for the changes to be reversible.

In the material from the American armies studied from this point of view, only a negligible number of patients were seen much earlier than ten hours after wounding, which explains why the results in the one-to-ten-hour category are not very much better than for the group as a whole (Chart 6). Infection is probably not an important factor in this category, though it plays an increasingly important rôle after the ten-hour period and undoubtedly accounts for at least a portion of the unhappy results in the group observed 20 hours or more after wounding. On the other hand, from the standpoint of possible reestablishment of the circulation, it is questionable whether a time-lag of more than ten hours is of special significance, since, as already pointed out, procedures designed for this purpose must be instituted within the upper limits of this period if good results are to be anticipated.

From the military standpoint, it is doubtful that the time-lag can be greatly reduced. Nearly half of it\* is taken up by the period between wounding and the administration of first aid. In World War II every effort was made to bring surgical care as near the front lines as possible, so as to cut down the time-lag, but it is highly unlikely that it could be instituted at the Battalion Aid Station level, or that it should be. The best that can be done is not always the best thing to do.

The establishment of vascular wounds as a special category, to be handled by a special routine, also does not seem practical.<sup>156</sup> For one thing, for such a classification to operate effectively would require of medical corpsmen a degree of differential diagnostic skill which they could not be expected to possess. For another, vascular injuries constitute such a small proportion of the total wounded that the imposition of another special category on the already overburdened military organization would seem scarcely justified.

Methods to preserve the circulation until patients with vascular injuries reach installations at which specialized surgery can be done are simply not practical. Supplemental sympathectomy, for instance, would be done with much greater difficulty in a Field Hospital than in a civilian hospital, and sympathetic block is open to the same criticism. The use of heparin before the patient reaches a hospital installation with laboratory facilities would be most unsafe, in view of the precautions necessary when any variety of anticoagulant therapy is employed, and might have disastrous consequences.

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\* In a group of 104 "first priority" patients studied in the Mediterranean Theater, the time-lapse from wounding to arrival at the first hospital installation (Field Hospital) varied between one and 34.5 hours and averaged 12.5 hours. The average time-lag between wounding and tagging (first aid) varied between a few minutes and 25 hours, and averaged five hours. The time-lag from arrival in the hospital to operation varied between one and 10.75 hours and averaged 3.75 hours. In a sample of 58 cases with vascular injuries, the time-lag between wounding and surgical treatment averaged 15.2 hours.

*Practical Difficulties.*—Ideal vascular surgery is difficult surgery. It requires special equipment, a great deal of time, and, on the part of the surgeon, highly specialized experience and dexterity.<sup>40</sup> The exigencies of the military situation are such that patients are not invariably seen by specialized personnel in the most Forward Installations. In Battalion Aid Stations they are observed by nonspecialized medical personnel, and occasionally only by military administrative officers; neither group is fitted or equipped to institute specialized treatment. Furthermore, even when they reach installations at which definitive surgery can be done, the ablest surgeons cannot produce

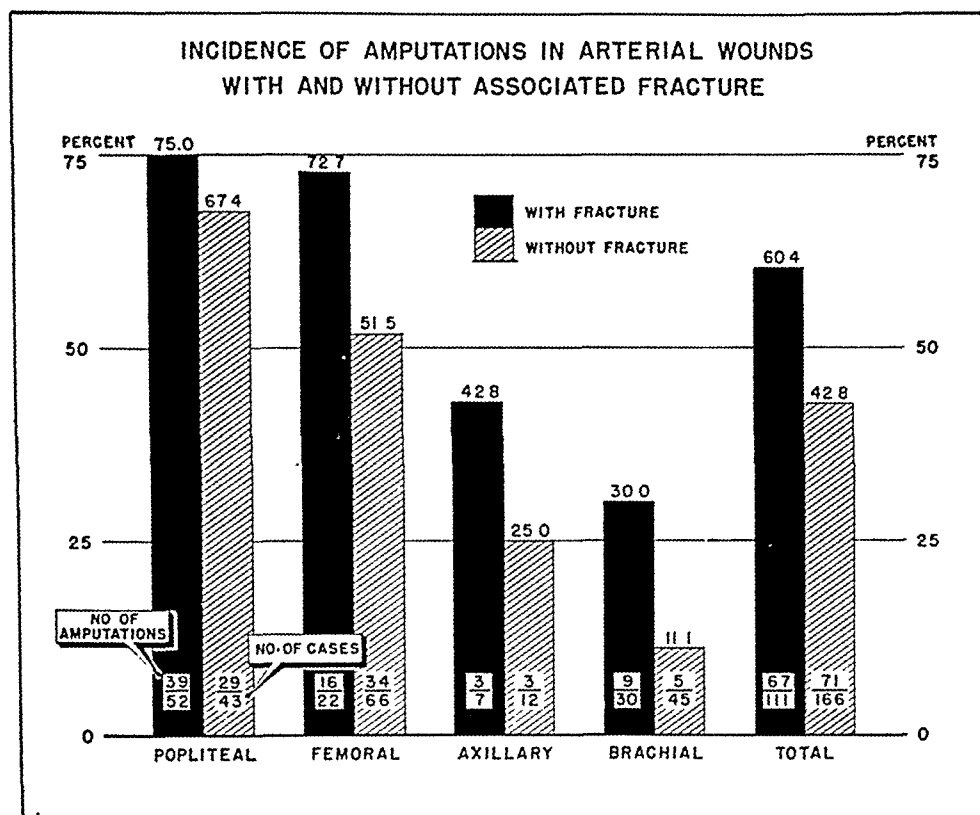


CHART 7.—Effect of presence or absence of associated fractures on incidence of amputation in arterial wounds of the extremities among American battle casualties in World War II.

outstanding results when they are working against factors beyond their control which, as will be pointed out, determine, far more than what they do, the outcome in any given series of cases.

*Associated Injuries.*—Vascular wounds, like all other battle wounds, occur singly in not more than two-thirds of the cases. They may be associated with other local wounds, which further impair or perhaps completely destroy the regional circulation. They may be associated with more remote wounds, some of which may require attention far more urgently, as a life-saving matter, than does the vascular wound; ideal vascular therapy must frequently be deferred for such a reason. Moreover, even if the vascular wound is single, the patient may be in such poor condition from exposure, loss of blood, or other causes that ideal vascular surgery must be postponed until he is in condition to withstand it. In other words, important as is the salvage of a limb, the salvage of life necessarily takes precedence of it.

To determine the possible effect of associated injuries, the presence or absence of fractures was studied, in relation to the outcome, in the material from the American armies (Chart 7). The incidence of amputation was significantly higher in the group in which vascular injuries were complicated by fractures, which suggests, in addition to the absolute significance of the observation, the importance of knowing all the circumstances about series of cases before drawing conclusions from comparative studies.

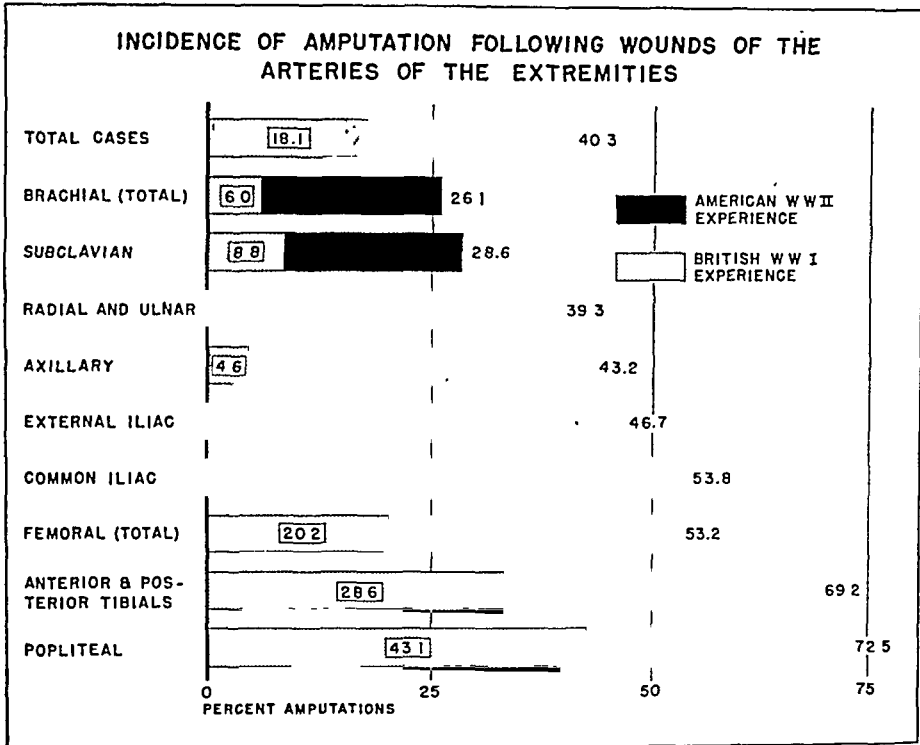


CHART 8.—Effect of site of arterial wounds of the extremities on incidence of amputation in American battle casualties in World War II and in British battle casualties in World War I.

Another consideration which might be mentioned at this time is the amount of blood the patient has lost. In the majority of vascular wounds there has usually been a considerable loss before first aid can be instituted. In a sample group of 27 patients studied a week after wounding, the red blood cell count still averaged only 2,700,000 per cu. mm., and the hemoglobin concentration in 24 of the cases was still only 60 per cent of normal, despite the fact that these patients had received whole blood in amounts that had been thought adequate. One of these patients, with a wound of the femoral artery, had lost 40 per cent of the normal blood volume when he was first seen.

Naturally, if the volume of the circulating blood is reduced, the amount of blood which passes through the peripheral arteries is also reduced, the circulation of the distal portion of the extremity with a vascular injury is still further reduced, and its nutrition suffers correspondingly. From both the systemic and the local standpoints a most important consideration in the therapy of vascular wounds is the prompt restoration of the circulating blood volume

and the hemoglobin concentration. The point deserves to be emphasized, for it is frequently forgotten that the patient with a wound of the extremity often requires an equal or even greater quantity of blood than a patient with a wound of the chest or the abdomen.

*Site of Wound.*—On the basis of actual experience and under the conditions or limitations imposed by military practice, the categorical statement can be made that the site and type of the vascular wound determine the therapeutic procedure and, therefore, predetermine, so to speak, the end-results. The American experience in World War II, as well as the British experience in World War I when detailed statistics were available for analysis (Chart 8), make clear that wounds of certain vessels, such as the popliteal artery, are much more likely to be followed by ischemic gangrene than are wounds of certain other vessels, such as the brachial artery. Indeed, for practical purposes it is possible to make up categories of critical and noncritical arteries. On the other hand, while a wound of either the anterior or the posterior tibial artery alone was relatively noncritical in the material studied, wounds involving both arteries resulted in the second highest proportion of gangrene in both the British and the American material. Generally speaking, lesions in the lower extremity are more serious than lesions in the upper extremity (Chart 9). A comparison of the incidence of amputations following wounds of the major arteries of the upper extremities (from the subclavian through the brachial) with those of the lower extremity (from the iliac through the popliteal) makes this clear. Furthermore, where the brachial and femoral arteries are concerned, whether the injury is above or below the profunda branch (Chart 10) plays an important rôle in the incidence of amputation. If the cases in which only single vessels of the forearm and leg (radial, ulnar, anterior and posterior tibial, and peroneal arteries) are excluded from the 2,453 arterial wounds of the extremities collected from American armies in various Theaters of Operation (Table I), the incidence of amputation after vascular injury rises to 49.6 per cent. If only wounds of the iliac, femoral and popliteal arteries and multiple arterial wounds of the leg are considered, it rises to 62.6 per cent (Table I). The British figures for World War I are similarly striking (Table I).

As these various figures show, in any unselected group of vascular injuries the proportion of poor results will be high or low, according to the number of important or unimportant vessels involved. The surgeon has no factor of choice, and, therefore, no responsibility, in this respect. The site of the wound is not of his selection, but he must necessarily institute therapy in reference to its location.

*Type of Arterial Lesion.*—The type, which to some extent is concerned with the size, of the arterial wound, has a two-fold importance: its effect upon the adequacy of the circulation in the distal portion of the wounded extremity, and its influence upon the type of surgical procedure possible. Generally speaking, the larger the injury, (1) the greater the chance that the collateral circulation will be damaged; (2) the more extensive the necessary débridement; and (3) the greater the chance of infection if débridement is not adequate.



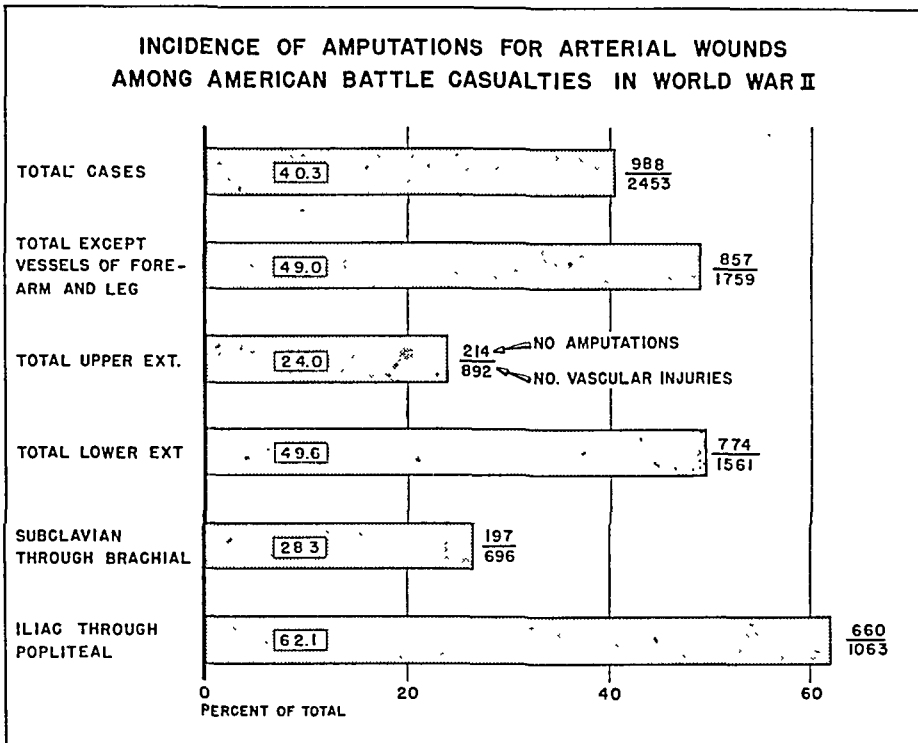


CHART 9.—Effect of site of arterial wounds of the extremities on incidence of amputation in American battle casualties in World War II.

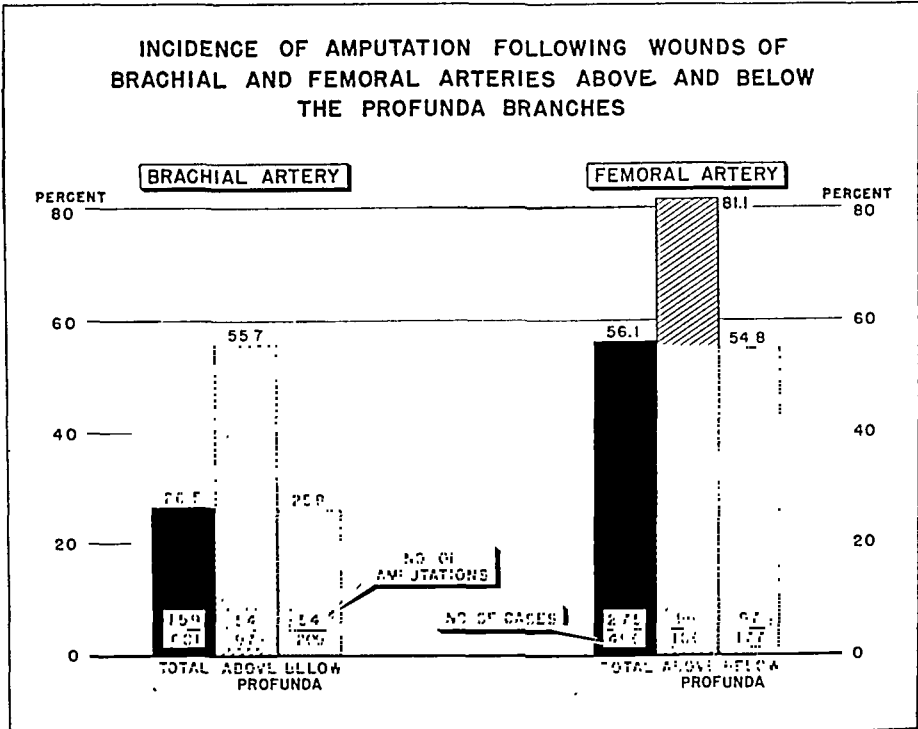


CHART 10.—Effect of site of wounds of the brachial and femoral arteries on incidence of amputation in American battle casualties in World War II. The 27 cases involving the profunda femoris (Table I) have been excluded as not pertinent to this consideration.

## INJURIES OF ARTERIES IN WORLD WAR II

In the American material, in the 620 cases in which the records were sufficiently explicit to permit separation of the injuries into distinct categories (Chart II), the incidence of amputation seemed definitely related to the type of lesion. It varied from 25 per cent in spasm to 70.5 per cent in thrombosis. A high incidence of poor results would be expected in the thrombotic category, since this type of lesion is likely to cause widespread interference with the flow of blood through the collateral vessels. In the category of spasm are included the few cases of contusion which were recorded as such, because contusion,

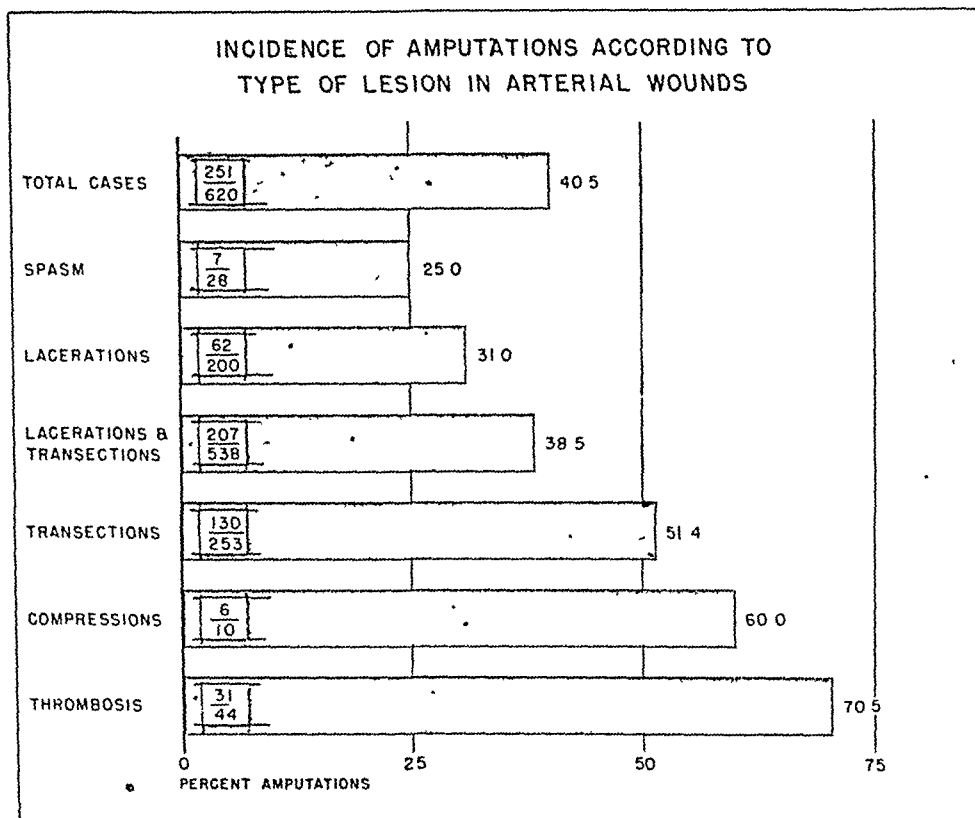


CHART II.—Effect of type of arterial wounds of the extremities on incidence of amputation in American battle casualties in World War II. The total number of lacerations and transections is greater than the sum of the individual lesions in this category because it could not be determined from 85 of the records which of these particular lesions was present.

if it is recognized at all, is not infrequently accompanied by spastic phenomena. This type of lesion, however, is usually not recognized (and, therefore, not recorded) and is usually slight. Its inclusion in a tabulated series is, therefore, likely to alter the results favorably, which is perhaps one reason why Makins' figures, which include contusions, are so much better than other series which omit them. Some doubt exists as to the incidence of 25 per cent of amputation in spasm. These figures are undoubtedly weighted, for in one sample of six cases, there were five instances of gangrene. This is so contrary to the usual experience as to suggest that the diagnosis of spasm was probably not correct in one or more of the cases in this group.

The majority of cases of laceration in this series (Chart II) were serious.

Minor lateral lacerations, in which conservative surgery was possible, were relatively few.

The category of lacerations and transections (which includes the 200 cases of lacerations, the 253 cases of transections, and a number of cases in which it could not be positively determined which of these lesions was present) presents an incidence of amputation which, as would be expected in view of its composition, lies midway between the incidence in lacerations, in which there may be a limited interference with the circulation, and the incidence in transections, in which there is abrupt interruption. Clean-cut transections were not the rule, there being tearing and loss of substance in most cases, associated with extensive damage to the collateral circulation.

The compression category includes only a small number of cases, so that the results are not statistically significant. Experience shows, however, that this is a very important group, because such injuries commonly complicate fracture and posterior displacement of the lower end of the femur. If this type of fracture, with its associated arterial lesion, is recognized and appropriate corrective steps are taken promptly, the complications which result from arterial compression can be avoided.

It seems scarcely necessary to elaborate further the importance of the type of wound in relation to the possible surgical procedure. As already intimated, the location and the type of the injury determine above everything else what the surgeon can do. The great majority of the wounds in the World War II series were produced by shell fragments, were large, were associated with extensive destruction of tissue, and (Charts 8-10) were not favorably located (Fig. 2). As a result, the vitality of the limb was gravely impaired before the surgeons ever saw most of the patients, thus jeopardizing the potential benefits of any therapeutic procedures employed.

*Infection.*—Infection is perhaps the least important of the limitations on therapy imposed by the circumstances of modern warfare. All battle wounds are potentially infected, it is true, but if adequate débridement can be done, surgical procedures directed toward the treatment of the vascular injury can be done at the same time with a high degree of safety. It is not infection, but the other circumstances just outlined, which now prevent reparative procedures in most battle injuries of the blood vessels.

It is granted that the views expressed in this section are extremely pessimistic. They are, however, equally realistic. In their defense it may be said that military surgery can be conducted only on a basis of profound realism, and that war is never a cheerful business.

#### THE RESULTS OF ACUTE OCCLUSION LIGATION OF THE MAJOR ARTERIES

The results of acute occlusion of major arteries in war wounds, whether caused by the injury itself or by ligation of the injured vessel, have not been clearly established. There are a number of explanations for the confusion which still exists on this subject.

Perhaps the most important reason is the fact that statistics generally quoted as representing the incidence of gangrene after acute traumatic occlusion actually represent no such thing, since most of them include instances of aneurysm as well. The two lesions are, of course, totally dissimilar. In acute occlusion (ligation) the blood flow is cut off abruptly. In aneurysm the occlusion occurs gradually, if at all, and by the time it has developed, or the aneurysm is excised, a more or less adequate collateral circulation exists.

Furthermore, in many series gangrene is the only unfavorable result recorded. The percentage of cases in which primary amputation had to be done because of the arterial injury is completely disregarded, and such series, therefore, do not truly represent the incidence of poor results in acute traumatic arterial occlusion. As for the various series in which amputation is included, the range is so clearly unreasonable—in popliteal arterial occlusion, for instance, it varies from 0 to 100 per cent<sup>142, 157</sup>—it is difficult to determine on what possible basis the calculations have been made.

Makins'<sup>128, 129</sup> statistics, which represent the largest collective experience in World War I, furnish an excellent example of the confusion which results from the inclusion of both acute and nonacute (aneurysmal) lesions in a single series. Actually, 49 per cent of his cases are aneurysms, and in certain vessels, such as the axillary and subclavian arteries, the proportion of nonacute lesions is more than 70 per cent. When (so far as possible) the favorable influence of aneurysm is excluded, his proportion of poor results rises from 18.1 per cent to 26.5 per cent. Yet his figures are repeatedly quoted, without qualification, as showing the incidence of gangrene after acute arterial occlusion. A similar lack of clarity is evident in the series collected by Salomon, Soubbotitch and others.<sup>15, 51, 69, 71, 72, 74, 77, 78, 83, 102, 104, 175, 211</sup> On the other hand, among 74 acute arterial lesions collected by Franz from German World War I statistics, the percentage of gangrene was 70.4. Mocquot and Fey also emphasized the gravity of these wounds, reporting an amputation incidence of 44 per cent among 61 they observed in a French Surgical Ambulance.

No large series of cases is available from the period prior to World War I to show the effect of ligation of major arteries in acute injuries. Sencert,<sup>187</sup> using statistics published before 1914, reported that the incidence of gangrene under these circumstances ranged from 5 per cent in the subclavian and brachial arteries to 50 per cent in the common iliac artery. the astonishingly wide range being explained, as the author himself pointed out, by the inclusion in the series of both aneurysms and acute occlusion.

On the basis of his personal military experience, Sencert<sup>188</sup> reported, in 1918, that ischemic gangrene had occurred only twice in 70 cases of vascular injury in which ligation was done a few hours after injury and in which no hematoma of any significance was present. The figures are confused, however, by the inclusion of four cases in which only veins (two internal jugular, two popliteal) were injured. When a diffuse hematoma had formed, the results were much less satisfactory; of 20 cases in which the axillary, femoral and

popliteal arteries were involved, gangrene developed in six. Sencert's own pronounced views as to the important rôle of hematoma formation in arterial injuries perhaps make the figures somewhat selective.

The results in Makins<sup>128, 129</sup> British cases collected in World War I are considerably better than the American figures collected in World War II (Chart 8, Table I). The data, however, are not fairly comparable, for a number of reasons: (1) The American figures include only acute lesions, while, as already noted, the British figures include both acute and nonacute lesions. (2) In 85 per cent of the American material the wounds involved important or critical arteries, while this was true of only 70 per cent of the British material (Chart 5). (3) It is possible, though exact statements cannot be made on this point, that there are excluded from the British figures some cases of gangrene and amputation which were classified as infections rather than as vascular injuries, as well as cases in which amputation was necessary for extensive trauma and other complications of vascular injuries. The American figures include among the poor results all the cases in which amputation was necessary after vascular injuries, whether as the result of complicating infection, so-called toxic absorption, gas gangrene, or any other cause. (4) Because of the more destructive weapons used in World War II, it may be assumed that tissue destruction was greater in the American cases of World War II than in the British cases of World War I. As a result, in addition to the main arterial injury, the collateral circulation was frequently and seriously impaired. (5) Because the wounds of World War II were more extensive than in World War I, débridement, which probably was more commonly practiced in the war just ended was a more extensive procedure. This comment must not be misunderstood. Débridement is an essential procedure, the omission of which would undoubtedly have resulted in a higher mortality rate, as well as in the loss of more limbs from infection. When properly done, however, it involves loss of tissue, and in extensive wounds its thorough performance inevitably entails additional damage to the collateral circulation.

As a matter of fact, although the American results in World War II at first glance seem to be much worse than the British results in World War I, they are probably better. The British series, as has been pointed out, includes a large number of cases of aneurysm, which are excluded from the American series, and in which, as Elkin<sup>59, 60</sup> and Shumacher have shown, postoperative gangrene is rare.\* In World War II the British surgeons have not been encouraged by their own results. At the Cairo Conference, in 1943, Ogilvie stated that in the course of the war he had not seen a single instance of ligation of the popliteal artery which had not been followed by gangrene, and Blackburn, in 1944, in a discussion of surgery in the Field, stated flatly that ligation of the popliteal vessels, in particular, almost invariably leads to amputation above the knee a few days later.

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\* In the combined series of 595 cases of aneurysms reported by these authors there was only one case of gangrene following operation.<sup>59, 190</sup>

THERAPEUTIC MEASURES IN WAR WOUNDS OF THE ARTERIES  
LIGATION

From the preceding discussion, it is clear that no procedure other than ligation is applicable to the majority of vascular injuries which come under the military surgeon's observation. It is not a procedure of choice. It is a procedure of stern necessity, for the basic purpose of controlling hemorrhage, as well as because of the location, type, size, and character of most battle injuries of the arteries.

From the technical standpoint, with reference to the optimal site for ligation, little discussion is necessary. At the present time, when wound infection is usually a controllable complication and when secondary hemorrhage is, therefore, not the factor of risk which it was in World War I, there seems no justification whatever for the performance of proximal ligation. It may be theoretically desirable to ligate at such a level as to avoid the creation of a blind pouch, but the deliberate effort to do so frequently involves extensive dissection and may still further jeopardize the circulation of the injured limb. The proposal was first made by Leriche and Policard, in 1922, and was reemphasized by Holman,<sup>87</sup> in 1944, and Rogers, in 1945.

*Ligation of the Concomitant Vein.*—The chief difference of opinion concerning the technic of ligation has to do with whether or not the concomitant vein should be ligated along with the injured artery. The amount of space devoted in the literature to this discussion seems curiously out of proportion to the value of the procedure, though the manner in which the practice evolved is rather interesting, and has been thoroughly reviewed by Brooks.<sup>25</sup>

Prior to World War I the current opinion seemed to be that the prognosis for survival of a limb after interruption of a major artery was worse if the concomitant vein was injured and had to be ligated simultaneously. Jacobson stated that under these circumstances: "Leave should be gotten at once for amputation." Matas<sup>131</sup> declared that "the danger of peripheral gangrene is always made doubly worse by the simultaneous injury of the accompanying or satellite vein." During World War I, however, a completely opposite point of view developed, with Makins as the originator and chief proponent of the practice for war wounds. Simultaneous ligation of the concomitant vein, in his opinion,<sup>128, 129</sup> is of distinct advantage for two reasons: 1. The capacious main vein affords too ready a channel of exit for the diminished arterial supply, as well as an undesirable reservoir of stagnation. 2. As the result of combined arteriovenous ligation, the smaller amount of blood supplied by the collateral arterial circulation is maintained for a longer time within the limb, and there is, therefore, an improvement in the conditions necessary to preserve its vitality.

Therapeutic venous ligation for venous disease has been known since the time of Hippocrates, but Makins seems first to have proposed it as part of the treatment for acute traumatic arterial lesions. He observed from his experiences in the South African war that a smaller incidence of gangrene followed traumatic arteriovenous fistula when both artery and vein were ligated than

when only the artery was ligated, though, as Brooks<sup>25</sup> pointed out, he did not record the observation until his Bradshaw Lecture, in 1913.<sup>124</sup> Of further interest in this connection is the fact that Makins<sup>125</sup> seemed still unprepared to advocate the procedure in his extensive article on vascular injuries of warfare, published in 1916, and simply stated: "With regard to the question of the danger of simultaneous ligation of the artery and vein, it may be added that this was done in one of the successful cases." In the Hunterian Oration,<sup>126</sup> however, which was delivered in 1917, he advocated the deliberate ligation of the uninjured concomitant vein in cases of arterial occlusion, and at this time.

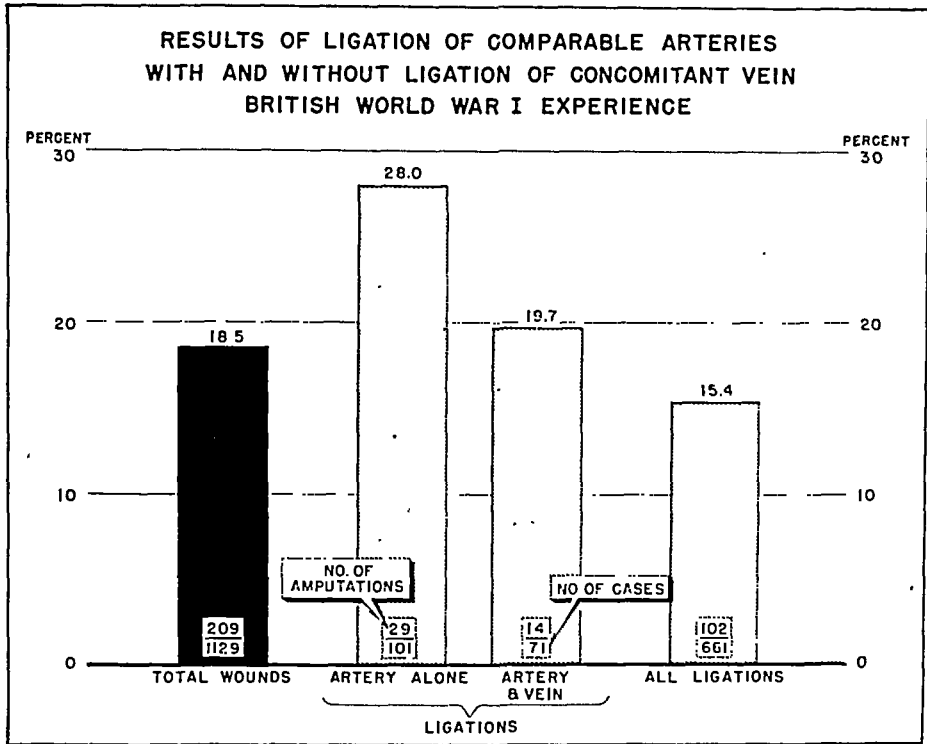


CHART 12.—Results of ligation of comparable arteries with and without ligation of concomitant veins in British casualties in World War I.

as well as in his monograph<sup>128</sup> published after the war, he set forth the evidence on which he based the suggestion and which may be briefly recapitulated as follows:

1. The demonstration in varicose veins of the ease with which a compensatory balance is attained when blood is diverted from the larger channels.
2. The lack of permanent vascular difficulties when the jugular and other large veins are ligated to prevent the diffusion of septic emboli.
3. The possibility of survival after occlusion of the vena cava.
4. His personal experience in arteriovenous fistula to the effect that quadruple ligation and excision are followed by less risk than simple arterial ligation.
5. Von Oppel's<sup>158-161</sup> good results in six cases of occlusion of the popliteal vein in senile gangrene, on the basis of his observation of the occasional good results which follow arteriovenous anastomosis in this condition and which he attributed to control of the venous circulation and the subsequent rise in the blood pressure of the limb.

6. Drummond's experimental demonstration that gangrene follows ligation of the mesenteric artery but not ligation of the mesenteric artery and vein. 7. Van Kend's experimental studies, which showed that local blood pressure was raised in the affected limb when the concomitant vein was ligated subsequent to occlusion of the artery.

The matter was fully discussed at the Inter-Allied Conference of Surgeons, held in Paris in May, 1917, and on the ground of Makins' statistics (Charts 12 and 13) the view was advanced that the concomitant vein should be ligated whenever a major artery was ligated, even if the vein itself was not injured.<sup>47, 93, 127</sup> Some surgeons<sup>46, 135, 136</sup> have accepted this view with some-

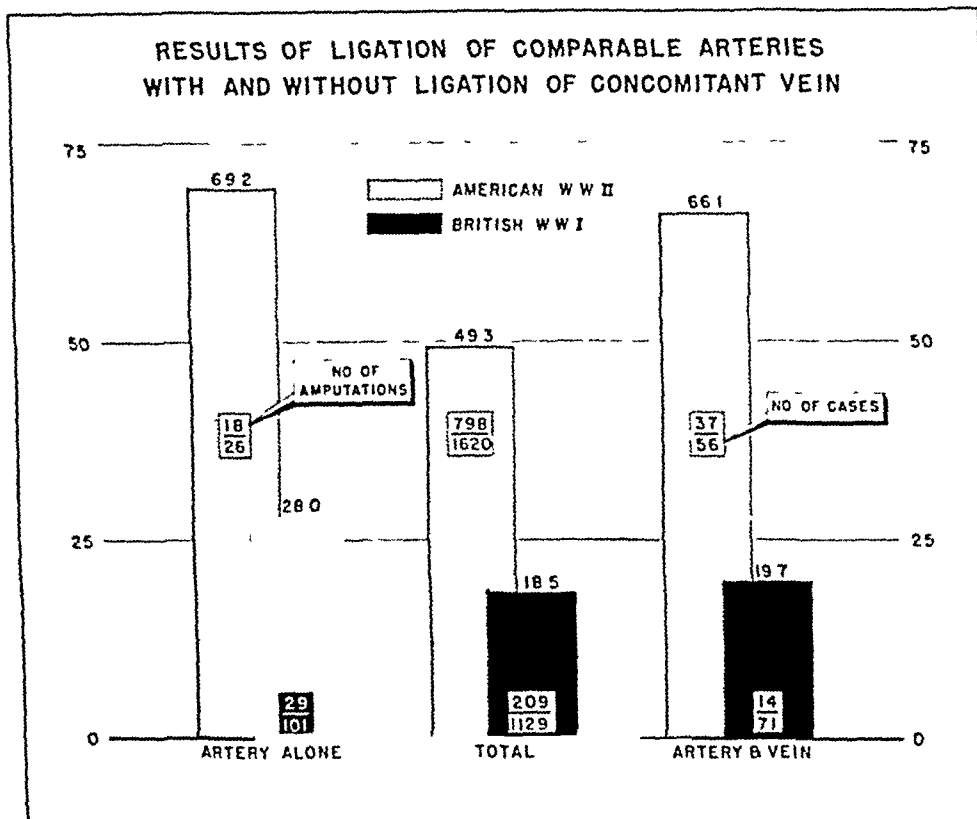


CHART 13.—Results of ligation of comparable arteries with and without ligation of concomitant veins among British casualties in World War I and American casualties in World War II.

thing less than enthusiasm; Maurer, for instance, wrote, in 1921, that concomitant vein ligation is not harmful and might be advantageous, and, in 1939, he had become even less enthusiastic. But the weight of Makins' prestige was so great that for the most part his point of view was accepted without question, and the practice of ligation of the vein became the rule when the artery had to be ligated.<sup>13, 14, 41, 51, 71, 72, 93, 144, 145, 188, 189, 201</sup>

Brooks, in an extensive review of the subject, in 1929, decided on the basis of clinical and experimental evidence<sup>28, 88, 166, 198</sup> that the concomitant vein should be ligated if the popliteal or axillary artery were injured, but that primary venous ligation should not be done if the common femoral artery were ligated, although subsequent ligation of this vein is recommended if signs of impending gangrene become evident. He considered that it made



little difference whether the procedure were performed or omitted if the femoral and brachial arteries were affected. More recently, additional experimental evidence to support this thesis has been published.<sup>117a</sup> Wilson, on the basis of an experimental study published in 1933, stated that his own results did not support the current belief that ligation of the concomitant vein diminished the incidence of gangrene following ligation of the main artery, and added that if the venous ligation were done at a higher level than the arterial ligation, the incidence and extent of tissue death would be increased. This receives indirect support from the observations of Montgomery<sup>148</sup> who found that the per-minute flow of blood to the extremity was reduced further following ligation of the concomitant vein in the extremity in which the artery had been previously ligated. The following year Brooks and his associates<sup>27</sup> published the results of an experimental study of 220 rabbits, 200 of which showed that massive gangrene of the extremity was 14.5 times less frequent after arterial and venous ligation than after arterial ligation alone, from which Brooks and his coworkers concluded that concomitant vein ligation was beneficial. Whereas this may be true for the rabbit, these results do not conform with those observed in man, as will be pointed out below.

While the experimental evidence for and against ligation of the concomitant vein is not always consistent, there seems no doubt, as Wilson has pointed out, that Makins' reasoning in favor of the procedure is not based upon sound physiologic concepts. Makins' often-quoted figures, furthermore, do not seem to warrant the sweeping conclusions which have been drawn from them. For one thing, the proportion of cases of arterial and of venous involvement is not clear, nor is the proportion of aneurysms in the two groups of cases. For another, the difference in the incidence of amputations (Chart 12) between the series in which only arterial ligation was done and the series in which the concomitant vein also was ligated is not statistically significant. Finally, the incidence of amputations in the whole group of wounds of comparable arteries in Makins' collected World War I series is actually less than the incidence of amputations in the series in which the concomitant vein was ligated, though the former series, on the basis of his theories, should provide the larger number (or at least an equal number) of poor results (Chart 12).

Aside from Makins' figures, not a great deal of evidence for or against ligation of the concomitant vein can be found in the literature of World War I. In 1916, which, it is of interest to observe, precedes the published views of Makins on this subject, Sehrt reported the incidence of gangrene in the upper extremity to be 7.8 per cent when the artery alone were ligated and zero per cent when the artery and vein were concomitantly ligated. The corresponding figures for the lower extremity were 20.4 per cent and 9.0 per cent. The numbers of cases are not given. On the basis of this experience, Sehrt concluded that concomitant vein ligation was of distinct value and expressed the belief that "impounding of blood (venous) in the extremity is beneficial." Propping, in 1917, influenced by these observations, attempted to provide experimental evidence to support the opinion that concomitant vein ligation is beneficial and

while the experiment was rather naive be concluded from it that gangrene of a limb after ligation of an artery is the result of an imbalance between the amount of blood entering the extremity and the amount of blood leaving it through the veins. In 1921, Heidrich, on the basis of 698 cases collected from the literature, concluded that the results were better when the concomitant vein was ligated. The incidence of aneurysm in these cases, however, was extremely high, which vitiates their significance. On the other hand, Punin stated, in 1921, on the basis of 64 personal and 1,057 collected cases, that the incidence of gangrene after the combined procedure was no less than when ligation of the vein was omitted. Brooks, in 1929, regarded the procedure not only as of no value but actually contraindicated.

The American experience in World War II (Chart 13) is not extensive. The majority of surgeons did not use concomitant venous ligation routinely, if at all, and the experiences of single surgeons are, therefore, insufficient to determine, one way or the other, the influence of the method on the end-results of vascular injuries. The collected figures seem to indicate that it does not in any way increase the chance of survival of the limb. The difference between the incidence of amputations in the series in which the vein was ligated and in the series in which it was not ligated is not statistically significant. The incidence of amputation in the total wounds of comparable arteries was considerably less than that in the group in which it was known that concomitant vein ligation was done, the difference being statistically significant, though, as was pointed out for the British figures, one would expect the results to be as good, if not much better, when venous ligation was done were the procedure of definitive value.

The conclusion seems legitimate, on the basis of Makins' figures for World War I and the American figures for World War II, that ligation of the concomitant vein furnishes no protection whatsoever against the development of gangrene after acute arterial occlusion and ligation in battle casualties.

#### SUTURE REPAIR

In addition to ligation, which permanently interrupts the flow of blood through the main channel, arterial wounds have been treated by suture, vein graft, and tube anastomosis. The consensus, at least on theoretic grounds, is that suture repair offers the greatest hope for survival of the limb, but practically, as has been pointed out, reparative measures are seldom applicable to such wounds. The operation should always be considered, however, circumstances permitting, for small lateral wounds, while less often it is a possibility in larger lateral wounds or in incomplete or complete transection.

The theoretic value of suture was recognized during World War I, but it was also realized that the number of cases in which it was possible were extremely few. Sencert wrote, in 1918, that ligation was the method *par excellence* for the arrest of hemorrhage from recent vascular wounds and that the indications for suture were exceptional. Makins stated that suture is the only method which provides ideal results, but added that it is applicable only in the primary stage and only if infection can be avoided. He regarded lateral wounds

of the larger vessels, that is, the carotid, brachial, iliac, femoral and popliteal arteries, as most suited for the method.

Bernheim,<sup>13, 14</sup> who had enthusiastically practised the Carrel method of suture in his civilian work, went to France with an elaborate personal equipment to use it in military surgery. In nearly two years overseas, however, at installations of various levels on several American fronts, he never saw any other surgeon perform it and he himself discontinued it in the few cases in which he attempted it, because of loss of supporting tissue as the result of necessary débridement and because of the unjustifiable amount of time which the operation required. Even in the case in which infection was absent he thought that military circumstances were unpropitious for vascular suture, while "only a foolhardy man," he remarked, "would have essayed suture of arterial or venous trunks in the presence of infections such as were the rule in almost all the injured."

Goodman<sup>70-73</sup> wrote enthusiastically of the advantages of suture, and stated that during a month's stay on the British Front in 1917 he was "enabled to refute the deductions made by the other surgeons present," the deductions being that the risk of gangrene after arterial ligation was sufficient to justify immediate amputation in injuries of the femoral, popliteal, and even the posterior tibial arteries. His personal experience, however, was limited to five cases, in one of which gangrene developed and amputation was required.

Not many other reports concerning the use of immediate suture in acute arterial wounds are available in the literature from World War I.<sup>57, 77, 78, 83, 96, 135, 144, 145, 187, 189, 194, 195</sup> Makins<sup>128, 129</sup> was able to collect only 39 cases. Three patients died, all from infection, and ideal to good results were obtained in about half of the remaining cases, the results being "in no way inferior to ligation," which seems somewhat faint praise. Goodman,<sup>71-73</sup> in addition to his own personal cases, presented a number of collected cases but the large number of aneurysms included in the group makes the figures of little value for comparative purposes. His collection includes a number of cases from the German literature, and there seems no doubt that German surgeons used suture more frequently than either British or American surgeons, though many series, such as that reported by von Haberer,<sup>77, 78</sup> consist chiefly or entirely of aneurysms. Gnilorybov, writing in 1944, stated that during World War I he had had several good results from vascular suture and that he saw no instance of gangrene after its use, in contrast to ligation, after which half of his cases developed gangrene. He did not cite exact figures.

The thorough débridement practiced in World War II, supplemented by chemotherapeutic methods, lessened the fear of infection which presumably discouraged a wide use of vascular suture in World War I. Nevertheless, the number of instances of vascular injuries in which suture was practised continued to be very limited, for the reasons already mentioned, that lateral wounds sufficiently localized to permit suture repair were seldom seen, and that the majority of wounds were accompanied by such widespread destruction of tissue and such loss of arterial substance that end-to-end anastomosis was rarely feasible.

The performance of suture was recorded in only 81 cases in the entire series of 2,471 arterial wounds which indicates the relative infrequency of the practicability of this procedure (Chart 14). Included in the group are three end-to-end anastomoses, of the common femoral, femoral, and popliteal arteries, respectively. Most of the cases were small lateral lacerations, involving a third or less of the circumference of the vessel. It is of interest that only one case in this series was a bayonet wound, and it was accidental; bayonet wounds, because they are cleanly incised and involve no great loss of tissue, would seem to be ideally suited for suture.

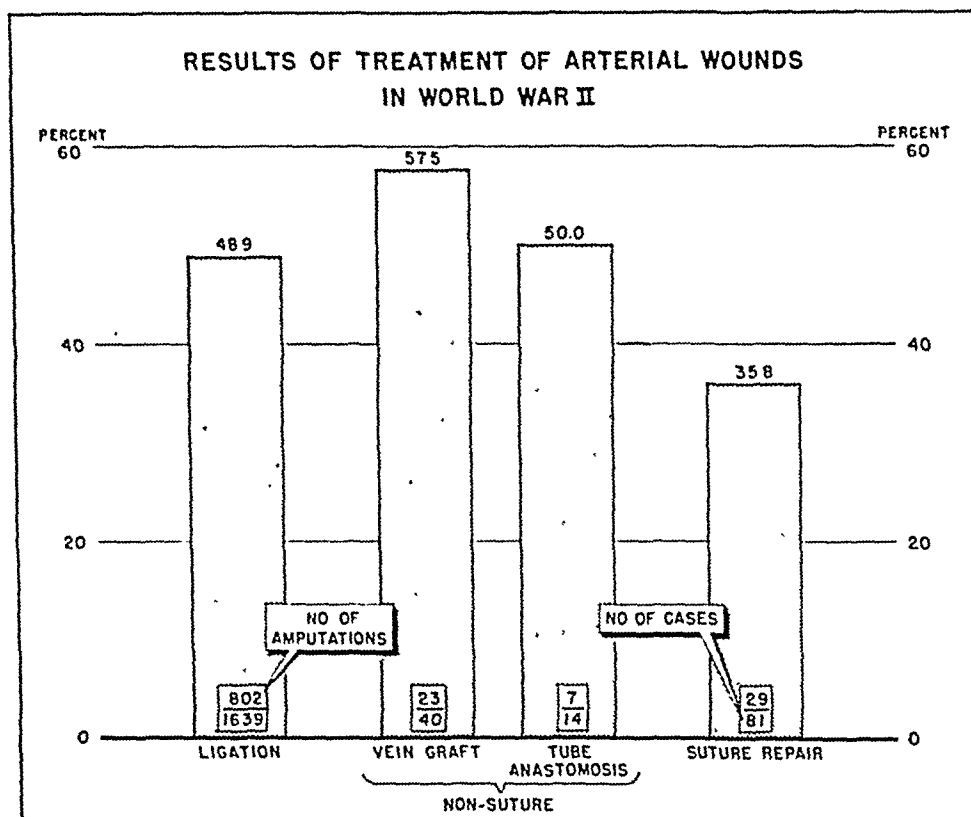


CHART 14.—Results of various therapeutic measures on incidence of amputation in arterial wounds of the extremities in American battle casualties in World War II, with special reference to the type of arterial repair.

The results of suture in these 81 cases are significantly better than the results of ligation in a larger series of 1,639 cases (Chart 14) and, indeed, are better than the results of any method of treatment employed. Not too much encouragement must be derived from these facts, however, for these cases formed a highly selective group of minimal wounds, without extensive tissue destruction. It would not be possible to duplicate or even to approach these results in the usual run of arterial wounds.

*Complications.*—The most important immediate complication of vascular suture is hemorrhage. The records are incomplete on this point, but secondary hemorrhage is known to have occurred in two of 24 cases included in the series of 81 cases in which suture was employed. Hemorrhage is usually a late development, occurring six to eight days after operation, by which time a collateral circulation has usually developed, so that ligation can be done with much less

risk to the limb than when it is a primary procedure. Thrombosis and embolism are other immediate but less frequent complications. They were not recorded in any case in this series. Late complications include arterial strictures and aneurysms; at the present writing the follow-up on the cases in this series is incomplete, and no statements can be made concerning their development following arterial suture.

#### OTHER REPARATIVE METHODS

Because of the extremely destructive weapons used in World War II, arterial wounds were often associated with extensive loss of substance. In the small number of such cases in which arterial ligation did not seem promptly



FIG. 1.—Completed nonsuture vein graft anastomosis of popliteal artery. The arterial injury was complicated by a severe compound fracture of the tibia through the knee joint and the dislocated tibial fragments are still attached in the wound.

indicated and in which suture repair was clearly impossible, some method of bridging the gap was considered desirable in order to restore continuity of the artery. Various methods have been suggested and practiced for this purpose, including the use of vein grafts and prosthetic tubes.

Sutured, as opposed to nonsutured, vein grafts had been suggested as a possible method of repair and successfully performed experimentally<sup>70, 76, 150, 151</sup> as well as clinically<sup>117, 207</sup> some years before World War I. Although the procedure does not seem to have been performed for acute arterial occlusion during that war, it was employed for traumatic aneurysms with surprising success.<sup>4, 23, 72, 73, 92, 178, 189, 207, 211</sup> In a series of 47 cases reported by Warthmüller, 40

were considered successful. As Matas<sup>133</sup> emphasized: "There is scarcely any need of grafts" for the type of case in which it was usually employed in light of the development of the technically simpler and highly successful Matas operation. To our knowledge the method was not used for these injuries in any American military installation in World War II. Because of technical and other difficulties, it has a very limited application, but a few successful clinical cases have been reported during this war, such as the seven cases each by Rehn<sup>176, 177</sup> and Killian, the six (of 10) by Schneider and Batzner, the single case by Murray,<sup>152</sup> and the unstated number by Khenkin. The majority of these cases were done on patients with aneurysms rather than acute arterial wounds.

The principle of nonsuture anastomosis originally developed by Payr, in 1900, thoroughly tested experimentally by Höpfner, in 1903, and successfully applied clinically by Lexer, in 1907, was employed by Blakemore, Stefko, and Lord,<sup>18-21</sup> in 1942 as a method of restoring the blood flow through severed arteries. They used vitallium tubes instead of magnesium alloy tubes which Payr and Höpfner had used, lined them with vein grafts, and tied the cut ends of the artery over the ends of the connecting cannula. Later they modified the method, using two tubes bridged by a vein graft, just as Höpfner had done. Their experimental and clinical results were highly encouraging and they were enthusiastic over the possibilities of the method in military surgery. Of historical interest, also, is the fact that Jeger,<sup>95</sup> in 1913 had advocated the method in military surgery.

During the recently terminated war, the Surgical Consultants Division in the Office of the Surgeon General supplied these vitallium tubes in assorted sizes to the various Theater Consultants, who distributed them to experienced vascular surgeons for trial in Forward Installations. Full details are not yet at hand, but the material analyzed in this communication shows that the double-tube-vein-graft technic (Fig. 1) was employed in 40 cases. The incidence of amputation was somewhat greater than after other methods of repair but the difference is not statistically significant (Chart 14).

A consideration of great importance in military surgery is the ease with which an operation can be performed, and experience indicates that nonsuture anastomosis is neither as simple nor as easy as its proponents, whose experience, of course, is extensive, state it to be. One operation, for instance, performed in an Evacuation Hospital, by a better-than-average surgeon, took three and one-half hours; in the course of the procedure the ligature twice slipped off the tube and had to be tediously reapplied. Complete information is not available as to the number of times this method of anastomosis was attempted but could not be completed, though it is known that this happened five times in one sample consisting of 23 cases. A possible disadvantage of the method in cases in which it cannot be completed is that additional arterial substance may be destroyed in the course of the attempted application of the tube (Fig. 2).

Bridging of the arterial gap by intubation to provide for temporary maintenance of the blood flow is a fairly old principle. In 1915, Tuffier, who rea-

soned from his experiences with the use of silver tubes in performing direct blood transfusion, proposed the use of these tubes for bridging arterial defects and was successful in a number of cases. Makins, in 1922, reported 12 cases treated by this method, four of which, however, were not acute lesions. One patient died of sepsis and one of gas gangrene, but the results were good in the remaining cases. Makins also mentioned Cowell's case, in which, following



FIG. 2.—Arteriograph 1.5 weeks after nonsuture anastomosis of popliteal artery, showing complete obstruction of the anastomosis. This case illustrates the possible damage to important arterial branches if too much of the artery is used in the anastomosis. The limb might not have survived if the branch to the gastrocnemius soleus group of muscles had not been spared. (Operation by Harbison and Simeone.)

ligature of a completely divided femoral artery, signs of gangrene ensued but the limb was saved by removal of the ligatures and the application of a Tuffier tube. The generally favorable opinion of the procedure is reflected in the writings of a number of authors during that period.<sup>24, 52, 72, 92, 128, 129, 201, 202</sup>

To accomplish the same objective as the silver tubes used in World War I,

glass tubes were suggested early in World War II.<sup>131</sup> While it is known that they were used by British and Canadian surgeons during this war, no details concerning their experience are available at this writing. The potential clinical value of the method was indicated by the successful experience of Murray and Jones in their experimental studies with heparin on dogs.

Plastic tubes were also suggested and employed in a similar manner as glass tubes. In the material analyzed there were 14 cases in which this method of repair was employed. Although the results obtained in this group of cases are not much different from those following other forms of repair, the series is



FIG. 3

FIG. 3.—Arteriograph 3.5 weeks after nonsuture anastomosis of superficial femoral artery, showing patency of the anastomosis and no evidence of undue ballooning of the vein segment. Clinically, the patient showed excellent peripheral circulation. (Initial operation at 8th Evacuation Hospital.)

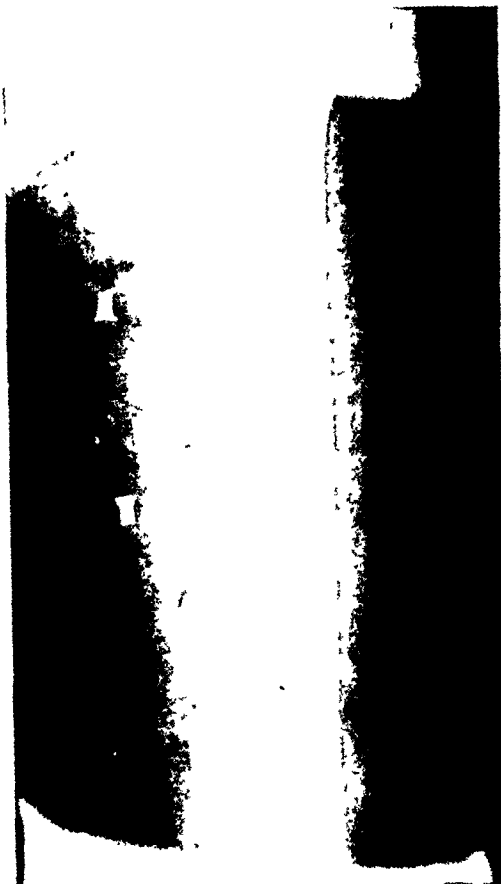


FIG. 4

FIG. 4.—Roentgenograph after nonsuture anastomosis of superficial femoral artery. The extent of the defect which may be bridged, as shown by the positions of the vitallium tubes in this instance, is often considerable. The repair was successful.

obviously too small to permit definite conclusions (Chart 14). Plastic prostheses have certain advantages over other prosthetic devices used in the repair of arterial defects. They are apparently well tolerated by the tissues, and since they can be altered in size and shape to fit the necessities of the special case, merely by soaking the basic material in warm water, a supply of tubes of various sizes need not be kept on hand, as is necessary when vitallium or glass



tubes are used. The technic of repair by this method is also simpler than when vitallium tubes are used. On the other hand, the possibility of thrombosis is probably greater than that following the use of vein grafts (Fig. 3).

The object of tube anastomosis in arterial injuries is the maintenance of the circulation of the injured limb while a collateral circulation is developing. If this objective can be achieved, the later gradual occlusion of the tube, with cutting off of the circulation in the main vascular channel, will have a much less deleterious effect than if these processes had occurred abruptly. To achieve the desired result, however, the patients must be seen early, and the irreducible time-lag, discussed elsewhere in this communication, makes this impossible in the majority of cases.

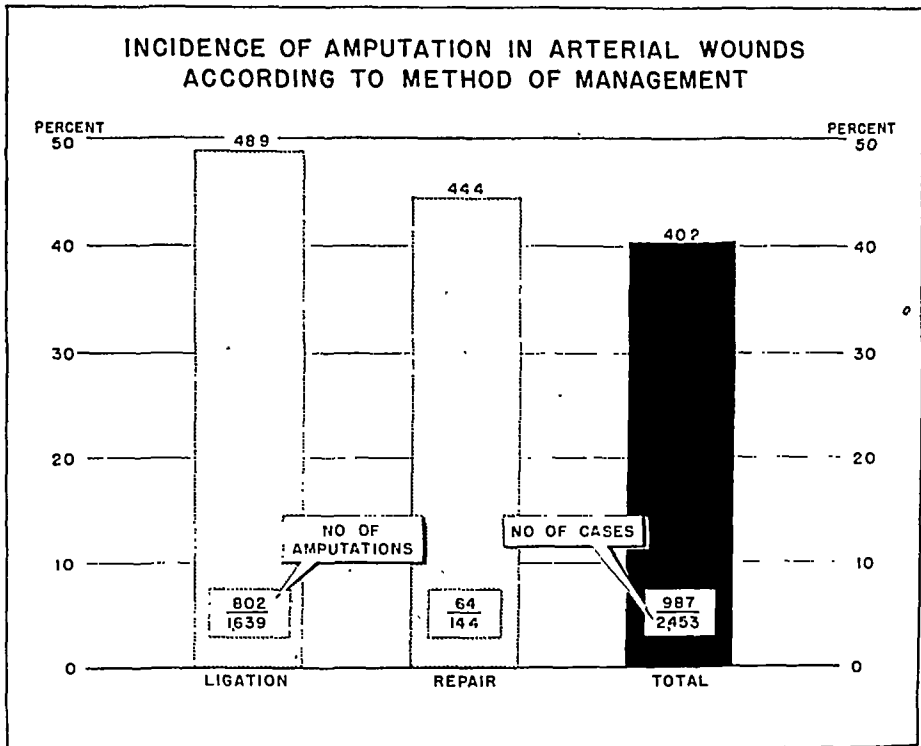


CHART 15.—Results of various therapeutic measures on incidence of amputation in arterial wounds of the extremities in American battle casualties in World War II.

A broader experience will be necessary to determine the usefulness of all nonsuture and other methods of arterial repair in war wounds. Individual cases (Fig. 3) can be cited in which it may be said that one or another method may have been responsible for the saving of all or part of a limb, but the overall figures (Chart 15) do not show sufficiently significant differences to warrant definitive conclusions. In all fairness, however, it must be said that the cases selected for trial were all cases in which suture repair was not feasible because of the size of the defect (Fig. 4) and in which the prognosis was grave, and the proportion of critical vessels involved was higher than in the series in which ligation was done.

### CONSERVATIVE (NONSURGICAL) THERAPY

For the sake of completeness a few words should be said about conservative (nonsurgical) therapy, which has been suggested for a small group of selected vascular injuries, in which it is hoped that uncomplicated healing will occur, or, if it does not, that aneurysm formation will take place. The almost negligible incidence of loss of limb after excision of aneurysms prompts the rather paradoxical statement that the best safeguard for the survival of a limb is to permit an acute arterial wound to develop into an aneurysm. The great majority of aneurysms occur accidentally, however, rather than as the result of deliberate surgical inaction. The principal objection to conservative therapy in battle injuries of the arteries is that it usually implies the omission of débridement, which is so essential a phase of the management of all war wounds that exceptions to its routine performance must be made with the greatest caution. Conservative therapy was advocated as a deliberate policy by some British surgeons<sup>30, 61</sup> at the Congress of C. M. F. Army Surgeons held in Rome in February, 1945, but few arterial wounds among American troops were deliberately treated by this plan. Three cases, in all of which the results were good, were treated conservatively by Sandzen and Evans in a series of 89 vascular wounds, 64 of which involved major arteries, and Rose, Hess and Welch treated eight of 100 cases in this way, also with good results. In four of the eight cases the wounded vessels were exposed during débridement, and in the other four instances, in each of which the popliteal artery was involved, they were not exposed at all.

The selection of cases for conservative management requires expert surgical judgment, as well as a good deal of courage. Generally speaking, it is best to explore even trivial wounds, with the idea of performing remedial or reparative surgery if there is evidence of complete interruption of the circulation.

### SUPPLEMENTAL THERAPEUTIC MEASURES

*Anticoagulant Therapy.*—Anticoagulant therapy, in spite of its value in selected cases in civilian surgery, has an extremely limited application in military vascular surgery. Its use immediately after wounding, as has already been pointed out, is impractical because its safe application demands that it can be used only in a hospital, where close clinical observation and repeated laboratory studies are possible. Mere arrival at the hospital, however, does not mean that anticoagulant measures can immediately be applied. They are not safe even then until (1) the patient has been properly examined and it has been determined that the injury is limited to the vascular wound, and until (2) the operation has been concluded. It may be theoretically possible to employ heparin or some similar agent before operation and to control the clotting time during the procedure, but it is doubtful whether even in a civilian hospital this would be a practical plan. In a military installation it would be neither practical nor safe.

In the last analysis, the time-lag between wounding and the safe period for the institution of anticoagulation therapy is likely to be so long that this measure is no longer useful when it could safely be applied: Thrombosis would

already have occurred and the distal portion of the extremity would have been deprived of blood for too long a period for the pathologic changes which occur in the absence of circulation to be reversible. On the other hand, in the individual cases of battle wounds in which anticoagulant therapy is indicated and conditions permit continuous, careful observation, with adequate laboratory checks, the method has a definite field of usefulness and should be employed. Data are not available as to how often anticoagulant therapy was used in vascular wounds by American surgeons in World War II, although it is known that it was employed only rarely. In one sample of 12 cases in which it was instituted (in some it was administered in Pitkin's menstruum)<sup>118</sup> as early as was considered feasible under the military conditions and in which careful studies were made no significant advantages were observed from its use.<sup>192</sup>

*Sympathetic Block and Sympathectomy.*—Considerable clinical and experimental evidence exists to show that vasospasm is a natural response to those forms of trauma which directly or indirectly affect vascular structures. Spasm of the major arteries in wounds of the extremities was recognized in World War I,<sup>48, 55, 103, 105, 113, 136, 137, 189, 196, 205, 206</sup> and has since been observed and studied clinically and experimentally.<sup>11, 35, 37, 38, 66, 68, 79, 84, 90, 112, 113, 116, 121, 147, 155, 172, 197, 209</sup> The degree of vasospasm varies considerably, ranging from localized constriction with consequent minimal ischemia to a more extensive and generalized involvement, especially of the collateral circulation, with consequent ischemia of a degree sufficient to produce actual gangrene. Rational therapy in such cases is based upon an attempt to counteract vasospasm and to produce maximum vasodilatation in the involved extremity. Since the disturbance is apparently due to a vasomotor reflex initiated in the traumatized tissues, and since vasoconstrictor impulses are transmitted by way of the sympathetic nerve fibers, interruption of these impulses by means of sympathetic block or sympathectomy has been suggested and practiced by numerous observers.<sup>16, 45, 66, 68, 75, 99, 100, 110, 113, 130, 155, 168</sup>

Interruption of the sympathetic impulses usually by chemical means (procain hydrochloride), was widely practiced by American surgeons in World War II, but in the material available for analysis it was possible to determine in only 278 cases that the procedure had been performed or had been omitted. The results of the analysis (Chart 16) provide no substantial evidence that this method was of any value. The incidence of amputation in the group in which sympathetic block was performed is only slightly less than the incidence for the group as a whole, while the incidence in the cases in which ganglionectomy was done is greater than for the entire series.

These figures might seem to suggest that sympathectomy is a valueless procedure, but familiarity with the clinical material permits a different, and more accurate, interpretation: As a rule, sympathectomy was used only as a last resort, when it had already become apparent that the limb would not survive, while sympathetic block was more frequently instituted as part of the immediate postoperative routine, being continued until the outcome in respect to survival or death of the limb had become obvious. In the light of this knowl-

edge the apparently poor results of sympathectomy and the better results of sympathetic block are more readily understood.

The difficulties of evaluating such procedures as these on a purely statistical basis should also be emphasized: In the first place, the effective performance of the block is frequently open to doubt, and in the second place, proper objective methods are lacking to determine the efficacy of the procedure, while suitable controls upon which to base an evaluation of results are also lacking. The survival or death of the limb, which at first glance might seem to be a critically objective test, actually is not: It does not permit a clear decision as to whether the therapeutic measures employed in a given case have influenced the results, and it can serve as a criterion only when sufficiently large numbers of cases are available for statistical evaluation.

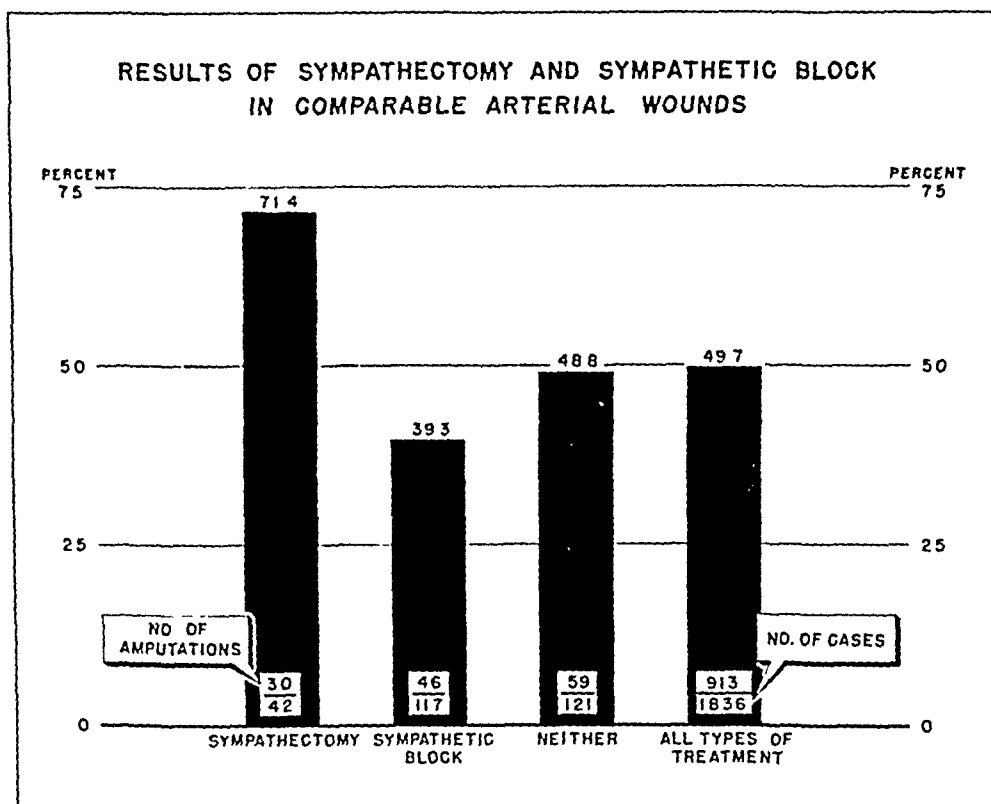


CHART 16.—Results of various therapeutic measures on incidence of amputation in arterial wounds of the extremities in American battle casualties in World War II, with special reference to sympathectomy and sympathetic block.

Perhaps the chief difficulty in critical evaluation of this method is the fact that in the great majority of arterial injuries the question of the viability of the part has been established at the time of wounding, and the margin within which improvement can be demonstrated is, therefore, so small that great numbers of cases are required to establish on a statistical basis the efficacy of any single procedure.

In spite of the lack of statistical data, however, there is considerable evidence in favor of sympathectomy and sympathetic block from personal experience and from the experiences of other surgeons. Cases can be cited in which moderate degrees of tense swelling and muscle pain characteristic of muscular

ischemia have regressed and in which the temperature of the limb has improved following ganglionectomy. In fact, the statement is perfectly fair that the experiences of most American surgeons working in the forward areas are to the effect that sympathectomy and sympathetic block were useful and beneficial procedures, regardless of inconclusive statistical evidence to prove the point.

Cohen<sup>38</sup> has taken exception to the theory that arterial spasm is influenced by local or distant autonomic reflexes, on the ground that it is myogenic in origin. In addition, he has cited evidence suggesting that blocking of the vasomotor control of the wounded limb is dangerous, because, he concludes, vasodilatation in the skin is not accompanied by vasodilatation in the muscles, and harm is done by diverting the blood from the muscles into the skin. He, therefore, deprecates the use of sympathetic block or sympathectomy as a therapeutic measure to combat traumatic vasospasm associated with direct injury. Curiously, however, he advocates the use of sympathectomy to control vasospasm associated with a crushing injury or following the prolonged application of a tourniquet, on the ground that the vasospasm observed in these types of vascular injuries is of a reflex nature. There are two obvious inconsistencies in Cohen's reasoning. The first is his assumption that vasospasm can be initiated reflexly by one type of trauma and not by another, even though the end-results of both, insofar as tissue damage, as well as ischemia and its consequences, is concerned, are the same. The second is his assumption that sympathetic block or sympathectomy can be both injurious and beneficial for vasospasm initiated by different types of trauma.

*Fasciotomy.*—The tense, hard swelling of the muscles of the forearm and leg frequently observed after complete obstruction to the blood supply of those parts has been related to rigor mortis (Fig. 5). Actually the two conditions are not identical, since in ischemic swelling the muscles appear to be contained under considerable pressure by the enveloping fascia. Following interruption of the main arterial supply to the muscles of the affected limb, a vicious circle promptly develops, in which the impairment of the capillary circulation is increased by the swelling of the muscular tissue and the pressure of the enveloping fascia, while the swelling and pressure are themselves increased by the increasing impairment of the capillary circulation. Eventually a stage is reached at which circulation ceases entirely.

On the basis of these assumptions, fasciotomy has been recommended not only for cases in which ischemic swelling has already developed but also for incipient cases in which progression seems likely. Longitudinal incisions are used in both upper and lower extremities. In the leg the incision is made posteromedially to decompress the gastrocnemius-soleus group of muscles and anterolaterally to decompress the anterior tibial compartment. In the forearm the incision is made on the volar aspect.

Fasciotomy is open to criticism on the ground that the incision may destroy the collateral circulation from the skin and may further compromise the regional circulation by introducing the risk of infection. On more theoretical grounds, however, these objections are superseded by the consideration that

fasciotomy may permit the reestablishment of circulation through the ischemic muscle.

Although certain British surgeons<sup>30, 36</sup> in the Mediterranean Theater were enthusiastic advocates of fasciotomy, American surgeons in this area were much less favorably impressed by it. In the limited number of cases in which it is known to have been used the results were occasionally good, though they were poor in the majority of the wounds of the popliteal artery in which it was employed.

*Refrigeration.*—The concept of reducing the metabolism of an injured part by cooling, to make metabolic activity commensurate with such circulation as



FIG. 5.—Tense swelling of muscles of calf, without significant subcutaneous edema, 12 hours after transection of popliteal artery. Fasciotomy may aid the capillary circulation in this type of case.

is available in it, is theoretically sound.<sup>22, 64</sup> On the other hand, the wisdom of actual refrigeration is still open to question for any purposes except to control infection and diminish lymphatic absorption from an infected limb prior to amputation, or to permit amputation without anesthesia in an aged and debilitated subject.<sup>50, 107, 179</sup> Moreover, several carefully controlled studies have clearly demonstrated that after refrigeration healing progresses less satisfactorily,<sup>107, 108</sup> wound infection tends to progress more rapidly and to be more serious,<sup>26, 31</sup> and the nerves in the cooled area are liable to damage.<sup>109</sup>

Certain advocates of refrigeration<sup>5-9, 44, 123, 170, 171</sup> have proposed the use of refrigeration under combat conditions, "particularly for military emergencies

with a sudden rush of battle casualties," and have charged the failure to use it widely under such circumstances to "inaction" on the part of the military services and "official negativism" on the part of the Committee on Medical Research.<sup>7-9</sup> The enthusiasm of the advocates of the method, while characteristic, clearly reflects an ignorance of the therapeutic limitations imposed by military exigencies. Aside from any other consideration, the chief argument against an extensive trial of refrigeration in military vascular surgery is the utter impracticability of attempting to apply it under battle conditions.

Amputation was required in three personally observed cases in which refrigeration was used in wounds of the femoral and popliteal arteries, which is in accord with the experiences of Auster, Snyder, and Ottoway and Foote. No evidence, in fact, exists that this method has saved limbs after wounds of the major arteries, and it is to be feared, as has already been indicated, that its prolonged use can lead to damage of the tissues which it is expected to preserve.

While the application of cold to the limb is not considered wise, the application of heat directly is equally unwise. The body is warmly covered, with the exception of the limb itself, which is left uncovered and is exposed to room temperature, with the object of minimizing local tissue metabolism.

*Oxygen Therapy.*—Since lack of available oxygen is one of the factors responsible for death of tissue after vascular occlusion, oxygen inhalation has been suggested as a method of supplying the lack. An increase in the oxygen saturation of the blood is easily effected by this means when oxygenation is impaired by intrathoracic wounds or similar causes. Under normal respiratory conditions, however, an increase in the partial pressure of oxygen in the inspired air has little effect upon the oxygen content of the blood. The slight increase (15 per cent) achieved by inhalations is made possible by an increase in the amount of oxygen dissolved in the plasma. Whether or not this increase results in a sufficient increase in the oxygen gradient between the capillary blood and the rest of the tissues to affect the outcome in arterial injuries is not known. Oxygen inhalation might be desirable, but it is doubtful that the slight benefits which might be achieved compensate for the difficulties inherent in the use of the method under combat conditions. It would seem more important to devote the effort to the correction of oligemia and anemia, with the object of improving the oxygen-carrying capacity of the circulating blood.

*Posture.*—The position of an extremity in which the blood supply is embarrassed as the result of disease or injury has long been regarded of some importance. In such conditions, and particularly in acute occlusions of the main arterial channels, the blood flow to the part is impeded and must be maintained through the collateral circulation. Elevation of the extremity above the heart level accentuates the ischemia by forcing the blood flow to overcome the amount of gravity pull created by the degree of elevation above the level of the heart. For this reason it appears more rational to maintain the extremity at heart level, or preferably in a slightly dependent position, even if a moderate degree of edema appears to be the result. The experience of American surgeons has, in general, confirmed the desirability of this procedure.

Cohen,<sup>38</sup> on the other hand, disagrees with both the rationale and the application of this principle. He advocates elevation of the limb, basing his recommendation on the belief that this "does not empty the arterial tree and cause capillary anoxia," and that it diminishes venous pressure and increases lymph flow, with consequent prevention of edema which would compress the capillaries. The available evidence on these controversial points is not sufficiently impressive, in our opinion, to permit definitive conclusions.

Physiologic rest of the injured limb is essential, both to reduce to a minimum the nutritional needs of the tissues and to limit infection and absorption of toxic by-products. This is best achieved by immobilization in a well-padded plaster of paris encasement, the upper half of which has been removed.

#### COMPLICATIONS AND SEQUELAE

As emphasized previously, this report has been concerned essentially with a consideration of acute or fresh wounds of the arteries. The local sequels of certain types of arterial or combined arterial and venous injuries, such as arterial hematoma ("pulsating hematoma"), traumatic false aneurysms, varicose aneurysms and aneurysmal varix, have been purposely omitted. In general, operative management of these lesions may be deferred for several months and is, in fact, preferable in order to permit the development of an adequate collateral circulation. Occasionally, however, certain complications arise necessitating operation, which may be urgent. These include hemorrhage, rapid expansion of the tumor, pressure upon contiguous structures such as nerves and blood vessels, infection and local pain. These complications are more liable to occur in arterial or "pulsating" hematoma and traumatic false aneurysms and are rarely observed in arteriovenous aneurysms. Occasionally excision of an arteriovenous aneurysm is indicated because of actual or impending gangrene in the periphery. Further considerations of these complications and their management may be found in a number of recent publications.<sup>12, 32, 34, 40, 42, 43, 58, 66-68, 80, 81, 86, 98, 100, 138, 149, 190</sup>

Other complications or sequelae include secondary hemorrhage, infection, vascular insufficiency, Volkmann's contracture, and causalgia. Secondary hemorrhage following vascular wounds was a common and greatly dreaded complication in previous wars.<sup>2, 51, 56, 74, 82, 125, 132, 133, 154, 168, 184, 188, 189, 200-202, 208</sup> During two years (1916-1918) of World War I, Waugh observed that among 10,000 patients with wounds involving long bones 14 per cent developed secondary hemorrhage in the first year and 9 per cent in the second year. He attributed the reduction during the latter period to "improved arrangements for adequate early excision of wounds." Tuffier,<sup>202</sup> in commenting upon secondary hemorrhage from arterial wounds during that period, stated that the incidence diminished "in proportion to the diminution of infected wounds." During World War II this complication has been observed relatively infrequently, as demonstrated by Freeman,<sup>65</sup> and by Warren. The former recorded its occurrence in only 23 (1.06 per cent) cases, 15 of which were associated with major blood vessels, among a series of 2,168 gunshot wounds. In over 9,500 casualties recorded by Warren, there were only 13 cases of secondary



hemorrhage severe enough to require operative interference or to cause death. The very low incidence and comparative insignificance of this complication in World War II is believed to be related to the lessened incidence of infection, which, in turn, is related to the performance of more adequate initial wound surgery.

Amputation after arterial wounds is done for one of two reasons, gangrene or infection. The so-called "toxic absorption," presumably the result of autolysis of muscle in the ischemic limb, for which amputation is done to relieve systemic manifestations, is probably of infectious origin in most instances. Table II shows the causes for amputations in 189 cases in this material in which amputations were done for vascular injury. The numbers, while small, suggest the relative frequency of all important complications after wounds of the arteries. When clostridial myositis and other infections are combined, it will be observed that nearly a fifth of the amputations were done for these two complications, whereas ischemia as a direct consequence of the vascular wound was the essential cause for the amputation in the remainder. In contrast with this experience, Turok<sup>53</sup> in an analysis of 49 cases of wounds of blood vessels sustained in the Finnish campaign of 1939 found that in the 12 cases requiring amputation only two were for ischemic gangrene whereas ten were for gas gangrene or infection.

Causalgia or causalgia-like conditions occasionally develop following arterial injuries and were observed during World War I,<sup>51, 111, 112, 114</sup> although a few reports<sup>53, 139, 140, 191</sup> on World War II experience have appeared in the literature. Accurate figures indicating the incidence of the condition after arterial wounds in World War II are not available. However, the complication is believed to be infrequent. This is supported by the observations of Mayfield and Ulmer, whose series of 75 cases included no patient with associated major vascular injury. In one group of 35 patients reported from a vascular center in the Zone of the Interior, causalgia was recorded only once. In another group of 77 patients, 17 cases of causalgia were observed. These figures are weighted, however, in that they include only the cases in which complications required the reference of the patients to vascular centers and do not include uncomplicated cases. It is of interest to observe in this group that the incidence of causalgia was much higher when nerve injuries were associated with the vascular injuries than when they were absent, the respective figures being 30 and 6.9 per cent. The great majority of these patients responded well to sympathetic block and sympathectomy.

After interruption of a major artery of a limb, the circulation may be so seriously impaired as to necessitate amputation of the limb; or it may be entirely adequate, so that a few weeks after the injury, there may be no detectable abnormality. Between these extremes are degrees of circulatory insufficiency which vary from symptoms brought on only after exertion to discomfort even at rest. Clinical manifestations consist of color changes, intermittent claudication, and sometimes, in the more severe cases, partial paralysis. Similar observations were made during World War I, and have been described by a num-

ber of authors,<sup>33, 111-114, 116, 128, 144, 145, 188, 189, 201, 202</sup> No accurate data are now available to permit statements as to the exact incidence of the condition. In one sample of 88 cases, however, vascular insufficiency severe enough to be manifested clinically was observed in 68 per cent. Two of the patients had had early sympathectomy and in 49 the operation was done late, with definite improvement in all but one. The concept of sympathectomy in these cases was developed by Leriche during the last war and this procedure apparently provided the best results that were reported in the management of this condition. Contractures involving the forearm and hand and less frequently the leg and foot constitute one of the most crippling sequels of acute ischemia consequent to arterial wounds. The conditions apparently develop as a result of severe ischemia just short of causing actual gangrene. It would appear to be essentially similar to Volkmann's ischemic contracture, which in civilian practice is usually observed in injuries associated with fractures.<sup>2, 62, 75, 89, 164, 169</sup> While it has not been possible to ascertain the incidence of this complication following arterial wounds, its occurrence has been relatively infrequent. In one sample of 35 cases of arterial injuries from a Vascular Center in this country there were four cases with contractures. In another sample of 77 cases from another Vascular Center there were 20 cases with contractures. While these proportions seem high it should be realized that these series of vascular cases are weighted by the fact that the Centers attract the complicated cases. The management of this condition has not been very satisfactory. Although efforts have been made to improve the circulation, including the use of sympathectomy, in general the results have been, at best, only moderately good. Other attacks upon the problem have taken the directions of orthopedic plastic operations and physiotherapy measures in the attempt to make the best use of whatever functioning muscle tissue remains.

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# TRAUMATIC ARTERIOVENOUS FISTULA INVOLVING THE ABDOMINAL AORTA AND THE INFERIOR VENA CAVA\*

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RECENTLY we have encountered and apparently have successfully repaired surgically an intra-abdominal traumatic arteriovenous fistula occurring between the abdominal aorta and the inferior vena cava, and situated at the level of the second portion of the duodenum. The fistula resulted from a gunshot wound.

We believe that a report of this case and the operation should be of interest not only because of the rarity of arteriovenous fistulae occurring at this site, but also because there have been satisfactory evidence and sufficient lapse of time since surgical repair to indicate that the patient has been relieved of a life-threatening cardiovascular disturbance. So far as we have been able to determine, this appears to be the only reported case in which an arteriovenous fistula between the abdominal aorta and the inferior vena cava in this site has been successfully repaired by surgical means.

Lehman, in 1938, reported a case in which an attempt was made to repair a spontaneous arteriovenous fistula that occurred between the abdominal aorta and the inferior vena cava, but death occurred from hemorrhage 15 hours after operation. Bigger, in 1944, reported a case in which a traumatic arteriovenous fistula involved the distal portion of the abdominal aorta and the inferior vena cava. The fistula was the result of a bullet wound. Surgical repair was carried out by proximal ligation of the aorta with tape and closure of the fistula by means of silk sutures passed through the wall of the unopened inferior vena cava. Three months after operation, the tape cut its way through the wall of the aorta and caused fatal hemorrhage.

Linton and White recently reported the successful repair of a traumatic arteriovenous fistula which occurred between the right common iliac artery and the inferior vena cava eight months after an operation had been performed for the removal of a protruded intervertebral disk. After preliminary sympathectomy, the portion of the right common iliac artery containing the fistula was ligated and divided proximally and distally to the fistula. Ligation of the right external iliac vein also was carried out.

**Case Report.**—A man, age 28, was first seen at the Mayo Clinic in July, 1943. In May, 1937, a stray 30-caliber rifle bullet had entered the right lower lateral portion of his thorax, between the fifth and sixth ribs. Complete sensory and motor paralysis of the lower extremities had developed immediately, and had persisted for one month. There

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had been no loss of sphincteric control. There had been a gradual return of sensation in the lower extremities. This had been followed by a slow return of motor function; about two months after the injury the patient had been able to be up and about, with only a slight limp involving the left leg. The limp also had disappeared gradually. For more than a year and a half he had been up and about. He had been able to take part in sports and had returned to work.

In March, 1939, the patient had begun to experience episodes of weakness, nausea and varying degrees of edema of the ankles. He also had noted that he tired easily. These symptoms had continued until December, 1940, when dyspnea had developed and the edema of the ankles had become more severe. He had been forced to stop working and had been placed on a cardiac regimen by his physician. This had consisted of rest in bed and the administration of digitalis for three months. His general condition had improved and in



FIG. 1.—Roentgenogram of the thorax made July, 1943, showing marked cardiac enlargement and bilateral pulmonary passive congestion.

spite of several episodes of pneumonia of mild degree, he had recovered sufficiently to resume his occupation in July, 1942. He had continued to work for 11 months, but in June, 1943, fatigue and edema of the legs recurred and he came to the clinic one month later.

The patient was a little less than medium height and weighed about 130 pounds (59 Kg.). His blood pressure was 180 mm. of mercury systolic and 80 mm. diastolic, and his pulse rate was 80. General physical examination revealed marked cardiac enlargement and a soft apical systolic murmur. Auscultation revealed a loud machine-like bruit which could be heard over the entire abdomen as well as over the entire back from shoulders to buttocks. The bruit was continuous and was accentuated with each systole. The maximal intensity of the bruit was in the right upper quadrant of the abdomen, just below the costal margin, but it was transmitted downward to the area overlying the external iliac arteries.

The values for the hemoglobin and the erythrocyte and leukocyte counts were normal. The Kline test on the serum was negative. The value for the blood urea was 36 mg. per 100 cc. Urinalysis revealed moderate albuminuria and a few granular casts and erythrocytes. Roentgenologic examination of the thorax revealed marked cardiac enlargement and bilateral pulmonary congestion (Fig. 1). The electrocardiographic tracing revealed left axis deviation, diphasic T waves in leads I and II and in precordial lead IV R, and delayed A-V conduction (P. R. interval 0.24 second). Roentgenograms disclosed what was described as a soft-tissue mass with a calcified periphery, situated to the left of the upper portion of the lumbar segment of the spinal column. Just below this mass, an opaque foreign body, which resembled a bullet, was seen (Fig. 2). An excretory urogram revealed that the excretory function of the kidneys was normal and that there was no gross deformity of either kidney. Neurologic examination did not disclose any abnormality.

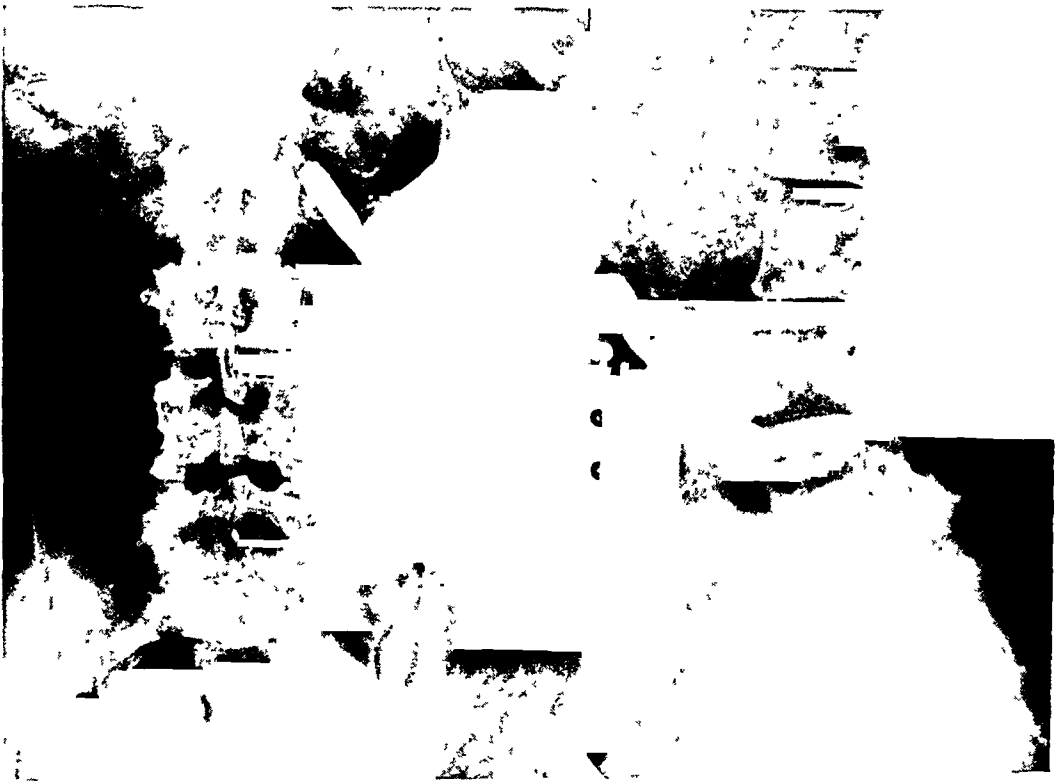


FIG. 2.—Roentgenograms, anteroposterior and lateral, made July, 1943, showing a soft-tissue mass with a calcified periphery situated to the left of the first and second lumbar vertebrae. The rifle bullet is visible just below the mass.

At this time, it was felt that the patient had an aneurysm of the abdominal aorta and also an arteriovenous fistula between the abdominal aorta and inferior vena cava, the exact site of which could be determined only by surgical exploration. It was felt that he had definite congestive heart failure as the result of the arteriovenous fistula and that unless the fistula could be closed the congestive heart failure would be progressive and fatal. The patient was advised to submit to surgical exploration to determine the exact site and the possibility of repair of the fistula but he preferred to postpone the operation.

The patient returned home and was able to do desk work for two or three hours a day. Nine months later, edema of the legs, dyspnea and cough developed in spite of digitalization. These symptoms were controlled with increasing difficulty by intravenous injections of salyrgan. He returned to the clinic in October, 1944, because of severe congestive heart failure.

Upon his arrival, he was markedly dyspneic at rest. His blood pressure was 190 mm.

systolic and 100 mm. diastolic. The heart was greatly enlarged; the apical impulse was in the midaxillary line at the level of the sixth intercostal space. The precordial systolic murmur had increased in intensity. There were many moist râles at the bases of the lungs, and the liver extended 3.25 inches (8.2 cm.) below the right costal margin. There was marked peripheral edema in both lower extremities. The loud machine-like bruit heard previously over the abdomen and back was still present. The value for the blood urea was 46 mg. per 100 cc. A roentgenogram of the thorax showed extreme cardiac enlargement and severe pulmonary congestion (Fig. 3). Roentgenographic examination of the abdomen again revealed an irregular globular-shaped ring of calcification just to the left of, and slightly anterior to, the first and second lumbar vertebrae. An excretory urogram, again, did not disclose any abnormality. The bullet was visible slightly below and anterior to the calcified mass. The patient decided to undergo surgical exploration.

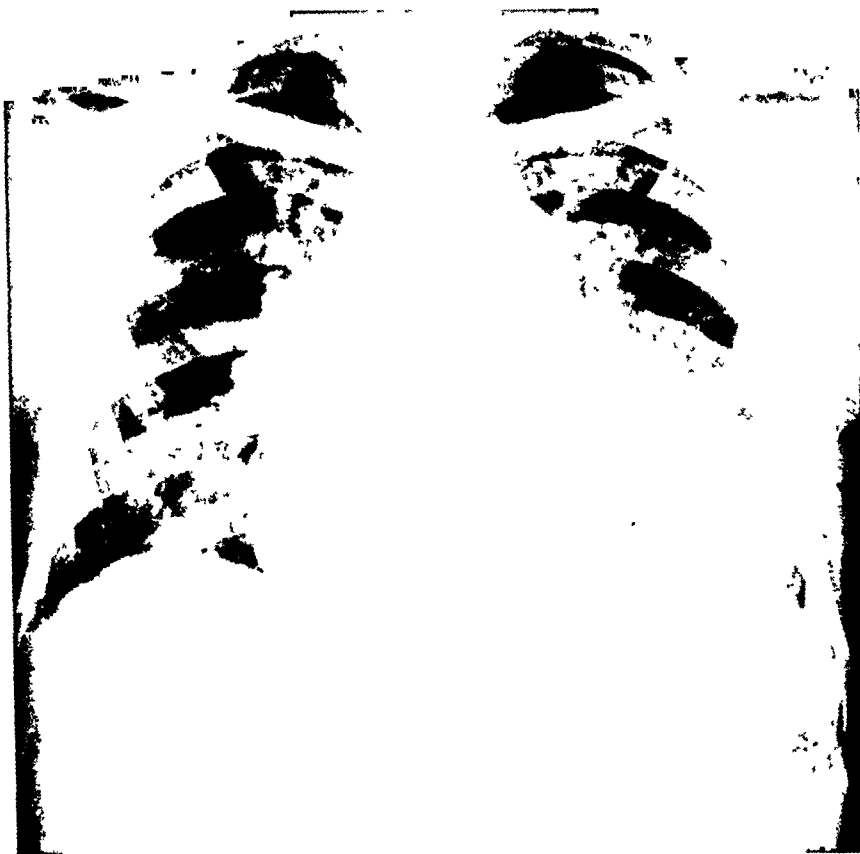


FIG. 3.—Roentgenogram of the thorax made October, 1944, showing extreme cardiac dilatation and passive congestion of the lungs.

He was hospitalized and placed on a cardiac regimen in preparation for operation. He was kept in bed and one cat unit of digitalis was administered daily. Four grams of ammonium chloride was administered daily for ten days. He was given a salt free diet, and his oral intake of fluids was limited to 1,000 cc. daily. Eight intravenous injections of salyrgan (2 cc. each) were given during a period of 18 days. Satisfactory diuresis occurred and he gradually lost 20 pounds (9.1 Kg.). It was felt that this represented edema fluid. His dyspnea disappeared and his liver became smaller. A few râles persisted at both the bases of the lungs. It was decided that his condition was satisfactory for surgical exploration.

*Operation.*—November 13, 1944: Through a right midrectus incision, under nitrous oxide-oxygen ether anesthesia administered intratracheally, the abdomen was explored. Palpation of the contents of the abdomen revealed a large tumor mass, 6 to 8 cm. in diameter. The mass was situated beneath the pancreas and extended across the bodies of the first and second lumbar vertebrae to the left side. There was a purring thrill which was most intense on the right side.

After the second portion of the duodenum had been mobilized, the hugely dilated inferior vena cava was exposed (Fig. 4). The vena cava was 5 to 6 cm. in diameter; it was adherent to the aorta and no distinct line of demarcation was apparent between the two vessels. The aorta appeared to be dilated; the dilatation was greatest above the exposed portion of the two vessels. When the aorta was palpated through the wall of the vena cava, the rush of blood through a fistulous opening could be felt. By pressing against the side of the aorta, through the wall of the vein, the fistulous opening could be blocked, and when this was done there was a distinct elevation of the blood pressure, which fell rapidly when pressure against the fistula was released. The opening between the aorta and vena cava was about 1 to 1.5 cm. in diameter when palpated through the wall of the vena cava.

After careful dissection, a cotton tape was placed around the vena cava above and below the fistulous tract. Then, while the assistant compressed the aorta with his fingers

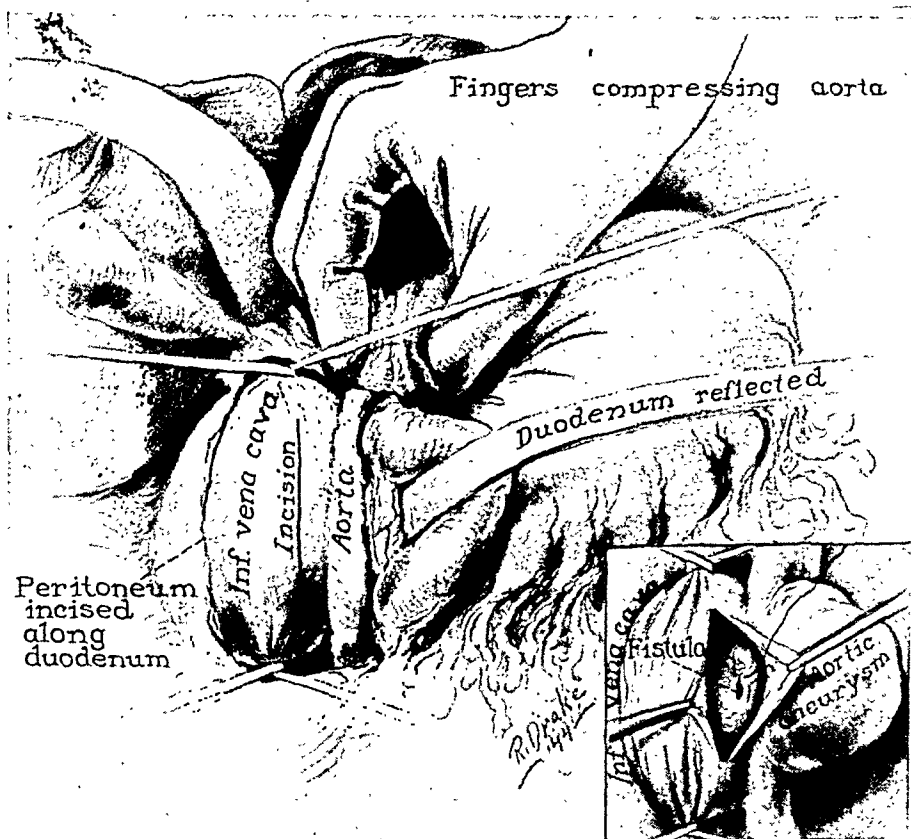


FIG. 4.—Exposure of the dilated inferior vena cava and aorta at the site of the fistula, after mobilizing the duodenum and head of the pancreas. The line of incision into the vena cava is shown. Inset shows the repair of the fistulous opening after opening the vena cava. Also shown is the aortic aneurysm to the left.

just below the diaphragm, bleeding through the fistulous opening could be controlled. A longitudinal incision was then made in the wall of the vena cava opposite the fistula, and by compressing the vein both above and below the fistula a reasonably dry field could be obtained so that the edges of the fistulous opening could be approximated with one row of silk sutures. When the compressed aorta was released, there was no leakage of blood through the closed fistula. The opening in the vena cava was closed with two rows of silk suture. There was some distention of the vena cava after closure, but the condition of the patient remained good. The tape which had been placed around the vena cava above the fistula was removed; however, the tape below the fistula was allowed to remain and

## AORTA-VENACAVAL FISTULA

its ends were brought out of the abdomen through the incision with the anticipation that, if postoperative bleeding should occur, traction on this tape would aid in its control. Five grams of sulfathiazole crystals were placed in the abdomen and the wound was closed without drainage. During the operation, a transfusion of 1,500 cc. of whole blood was given. The condition of the patient was excellent when he left the operating room. A record of the blood pressure and pulse made at intervals of 15 minutes during the operation revealed a lowering of both systolic and diastolic pressure, with a notable decrease of the pulse pressure, as well as a slowing of the pulse rate; these changes occurred simultaneously with closure of the fistula (Fig. 5). The blood pressure, which before operation had been 160 mm. systolic and 82 mm. diastolic decreased to 130 mm. systolic and 70 mm. diastolic after operation. The pulse pressure decreased from 78 mm. to 60 mm. and the pulse rate decreased from 110 to 100 beats per minute.

On the following day, the patient's rectal temperature rose to 103° F., where it remained for six days before it suddenly fell to normal. A roentgenogram of the thorax showed evidence of mild passive congestion, but there was no evidence of pneumonia. The pulse rate persisted at 110 to 120 for six days but the pulse was regular and of good quality.

During the first six postoperative days the output of urine was low. The value for the blood urea increased to 162 mg. per 100 cc. by the fourth day. Intravenous administration of a 10 per cent solution of glucose in distilled water, digitalis, and aminophylline caused a great increase in the urinary output and the value for the blood urea dropped steadily to a normal level by the sixth postoperative day.

The patient was allowed out of bed on the 13th postoperative day. At this time, a roentgenogram of the thorax revealed a marked reduction in the size of the heart and did not disclose any evidence of pulmonary congestion (Fig. 6).

The patient's strength steadily improved and he was dismissed from the hospital on the 24th postoperative day. During the convalescent period of 23 days in the hospital, the blood pressure remained relatively high, but the pulse pressure and the pulse rate remained at more nearly normal levels (Fig. 7).

At no time since the operation has there been any audible murmur over the abdomen. There has been no dyspnea on mild exertion, and the heart sounds have remained of good quality. The systolic murmur, which was heard at the precordium prior to operation, disappeared. Arterial pulsation in the lower extremities has remained good. Sixty-four days after the operation, the patient's referring physician found that the blood pressure was 125 mm. systolic and 90 mm. diastolic.

When the patient returned to the clinic for a check-up five months after the repair of the fistula, no evidence of recurrence could be found. There was no dyspnea on moderate exercise, although the blood pressure had reached a level of 170 mm. systolic and 130 mm. diastolic and the heart was found to have remained moderately enlarged. The patient had been doing clerical work daily for a number of weeks and said that his health was excellent.

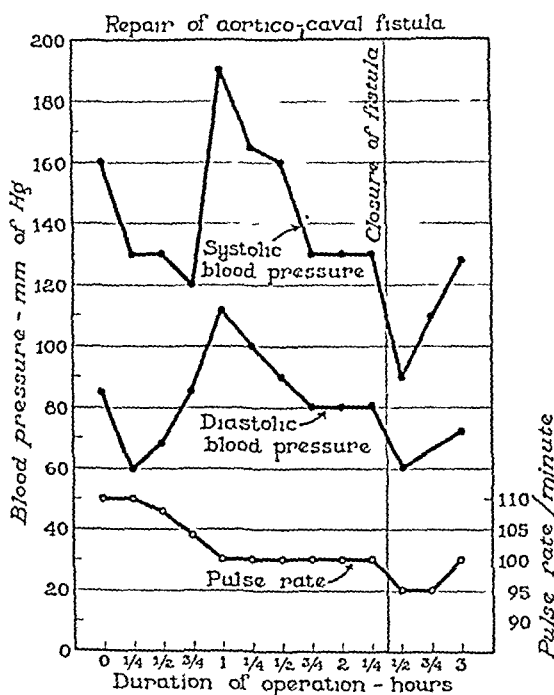


FIG. 5.—Record of blood pressure and pulse rate at 15-minute intervals during operation.



The patient returned to the clinic for a brief check-up November 19, 1945, approximately one year after the operation. He had been feeling well and had been working, but he had had an attack of acute asthmatic bronchitis and an episode of congestive heart failure one month previously. Under treatment he had recovered rapidly from this and was again ambulatory and working. There was no evidence of recurrence of the fistula. Cardiac hypertrophy and hypertension had persisted.

COMMENT.—Since the first accurate description by William Hunter, in 1761, of peripheral arteriovenous fistula, and its local signs and symptoms, much has been written and many studies have been carried out to clarify the changes in physiology and the cardiovascular disturbances which may be produced by this lesion. The majority of the reported studies and observations



FIG. 6.—Roentgenogram of the thorax made 13 days after operation, showing a marked reduction in the size of the heart and the absence of pulmonary congestion.

have been primarily concerned with arteriovenous aneurysms and fistulae occurring in the extremities. This is readily understood when it is kept in mind that a large majority of abnormal arteriovenous communications occur at these sites.

In the consideration of abnormalities of the larger vessels, it has been recognized that the physiologic effects of arteriovenous fistulae are more complex than those of arterial aneurysms. The former have a tendency to produce generalized disturbances, while the latter result in more localized changes in the region supplied by the vessel involved. Studies and observations by Reid,<sup>15-17</sup> Holman,<sup>4-7</sup> Matas,<sup>14</sup> Makins,<sup>11, 12</sup> and many others, have served to emphasize

the serious and often life-threatening effects of abnormal arteriovenous communications and have contributed notably to the development of adequate methods of management.

It is a well-known fact that a traumatic arteriovenous fistula between a large artery and vein in an extremity creates a definite alteration of cardiovascular physiology. It lowers the diastolic arterial blood pressure by decreasing peripheral arterial resistance. It produces more or less ischemia of the distal part of the extremity by shunting blood away from the extremity. It increases venous pressure and venous congestion in the extremity to a marked degree, and this increased venous pressure extends back to the right auricle—probably the most serious disturbance of all. The heart attempts to compensate for increased return of venous blood and decreased peripheral arterial resistance

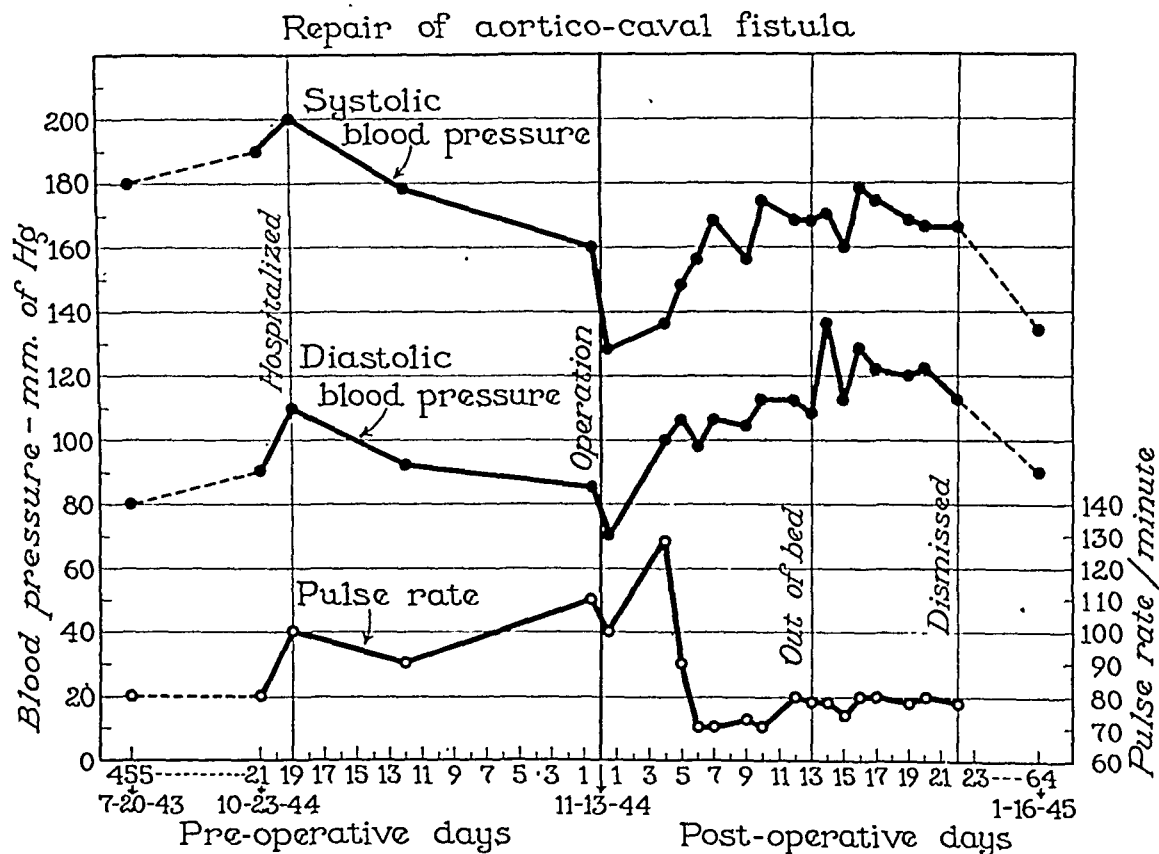


FIG. 7.—Record of blood pressure and pulse rate at intervals from the first admission through the period of convalescence from operation, demonstrating postoperative decrease of pulse pressure and lowering of the pulse rate.

by tachycardia and increased contractions, but its function continues to be impaired. Although the heart may gradually undergo hypertrophy and remain compensated for years, congestive heart failure ultimately will develop and this threat of congestive heart failure is the main reason why it is advisable to close such a fistula surgically before too much damage is done to the overburdened, overworked myocardium.

It would seem obvious that a large fistula between the aorta and inferior vena cava would create a much greater disturbance in cardiac physiology than would a fistula between an artery and vein of an extremity. It probably pro-

duces less peripheral ischemia and congestion distal to the fistula because these are distributed over a greater vascular bed.

The case which we have reported illustrates that progressive and serious congestive heart failure develops as the result of such a fistula.

Little has been written concerning arteriovenous fistulae occurring within the abdomen, principally because of the rarity of their occurrence at this site and secondly because of the difficulties which are encountered in their repair by surgical means. It is probable that the rarity of occurrence of traumatic arteriovenous fistulae between great vessels within the abdomen is due, in part, not only to their protected situation deep within the body cavity but also to the lack of surrounding tissue which might serve to support and reinforce an injury to these vessels. Free and exsanguinating hemorrhage, rather than formation of a localized hematoma, undoubtedly is the most frequently occurring consequence of trauma involving the aorta and vena cava. It is also probable that the fact that both aorta and vena cava were injured by the bullet instead of the aorta alone actually saved the patient's life, since this permitted bleeding from the aorta into the vena cava rather than into the anterior lumbar tissues and peritoneal cavity.

In recent literature attention has been drawn to the applicability of occlusion of the abdominal aorta, a procedure necessary for the cure of most aneurysms and fistulae in this region. Bigger and Elkin, among others, reviewed the literature from the first recorded instance of ligation of the abdominal aorta performed by Sir Astley Cooper in 1817, up to 1940, and found that although the abdominal aorta had been ligated in 28 instances, in only seven was survival of life sufficiently long to demonstrate that occlusion of this vessel is not necessarily fatal. Elkin emphasized that, aside from the technical difficulties involved in ligating the aorta, there are other features which may account for the hesitancy to occlude completely this vessel, such as the site of the aneurysm or fistula, the lack of efficient collateral circulation about a lesion at this site, the effect of ligation on the heart, and the problem of obtaining a type of ligature and a technic of occlusion which would preclude cutting or rupture of the vessel or reopening of the channel.

Arteriovenous fistulae involving the aorta and vena cava may be congenital or acquired. The acquired type includes both spontaneous and traumatic fistulae. Most of the arteriovenous fistulae that involve the aorta and vena cava are traumatic; those of the spontaneous type are almost all the result of syphilitic arterial disease. Spontaneous arteriovenous fistulae are unusual below the diaphragm and the majority occur within the thorax. Schweiger, Burchell and Baggenstoss were able to find 124 cases of spontaneous communications between large arteries and veins of the thorax in a review of the literature up until 1938. In a recent report of great interest, Alexander and Byron described the successful surgical removal of an aneurysm of the upper part of the descending portion of the thoracic aorta in which ligation of the aorta was successfully accomplished. However, the patient already had a congenital coarctation of the aorta. Ryle, described a pathologic specimen placed in Guy's Hos-

pital museum, in 1892, illustrating a fistula between the inferior vena cava and the abdominal aorta at its bifurcation. Matas,<sup>13</sup> in 1909, stated that until that time Boinet had found only 20 cases of arteriovenous fistula involving the abdominal aorta and inferior vena cava in a series of 114 cases of the spontaneous type. Lehman, reviewing the subject up until 1938, was unable to find any additional cases reported between 1909 and 1938. In none of these cases had successful surgical repair been accomplished.

#### SUMMARY

This report is based on a case in which a traumatic arteriovenous fistula was caused by a bullet wound, situated between the inferior vena cava and abdominal aorta, at the level of the first and second lumbar vertebrae. The fistula was repaired surgically, and up to the present time the patient has not exhibited any symptoms or signs of recurrence of the fistula.

This case, and the operation, should be of interest because of the unusual site of the fistula and because it is believed to be the only reported case in which the patient has survived a reasonable length of time after surgical repair to furnish evidence that the operation has been successful.

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# CIRSOID ANEURYSM OF THE SCALP\*

## REPORT OF FOUR CASES

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IT IS WELL KNOWN THAT TRAUMA, frequently inconsequential, may be the starting point of vascular tumors which are not only disfiguring but are definitely hazardous to life because of the possibility of severe hemorrhage from them. Therefore, it might be expected that war injuries would give rise to such tumors in increasing numbers.

It is the purpose of the present report to call attention to a particular lesion of this type; namely, that which affects the scalp and which arises either independently or through the existence of a preëxisting vascular abnormality of a congenital angiomatous nature. Four lesions of this character, and in this location, have been encountered in the course of performing operations upon approximately 470 aneurysms and arteriovenous fistulae, which resulted from wounds of warfare.

This condition must have been recognized from the earliest times in view of its striking characteristics and it is not at all improbable that some ancient example may have given rise to the legend of the serpents in the hair of Medusa. The term *aneurysme cirsoide* (varix-like) was first used by Breschet, in 1833. Other designations such as *aneurysma serpentinum* (Cruveilhier), and *aneurysma racemosum* (Virchow) have been introduced into the literature, but the term "cirsoid" has been generally accepted in English literature as a descriptive term for these lesions.

Congenital telangiectases, nevi, or angiomas which occur most commonly on the face and scalp may be the starting point of these tumors, particularly if intermediary trauma or long continuous irritation has occurred, as was true in Case 4. On the other hand, multiple communication between vessels may follow trauma without the apparent presence of a preëxisting vascular lesion, as was seen in the other three cases. When contributing arteries and outgoing veins form multiple anastomoses, the lesion becomes a diffuse arteriovenous fistula, and to these the term "cirsoid" is generally applied.

One of the most remarkable examples of this condition is the case reported by H. Müller,<sup>1</sup> in 1891, from the Clinic of Paul Bruns. This paper was accompanied by a drawing showing the postmortem dissection of the lesion, which is reproduced here (Fig. 1). It is the purpose of the present communication merely to record four outspoken examples of cirsoid aneurysm of the scalp, without attempting to cover the literature on this extensive subject.

The question of an intracranial extension of the lesion or extracranial

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manifestation of a primary intracranial varix should always be borne in mind since there are unquestionably reported instances in which this has occurred. Such was not the case in the four patients here reported, since communicating vessels extending through the skull were not encountered.

A number of these cases have been reported and many have been success-

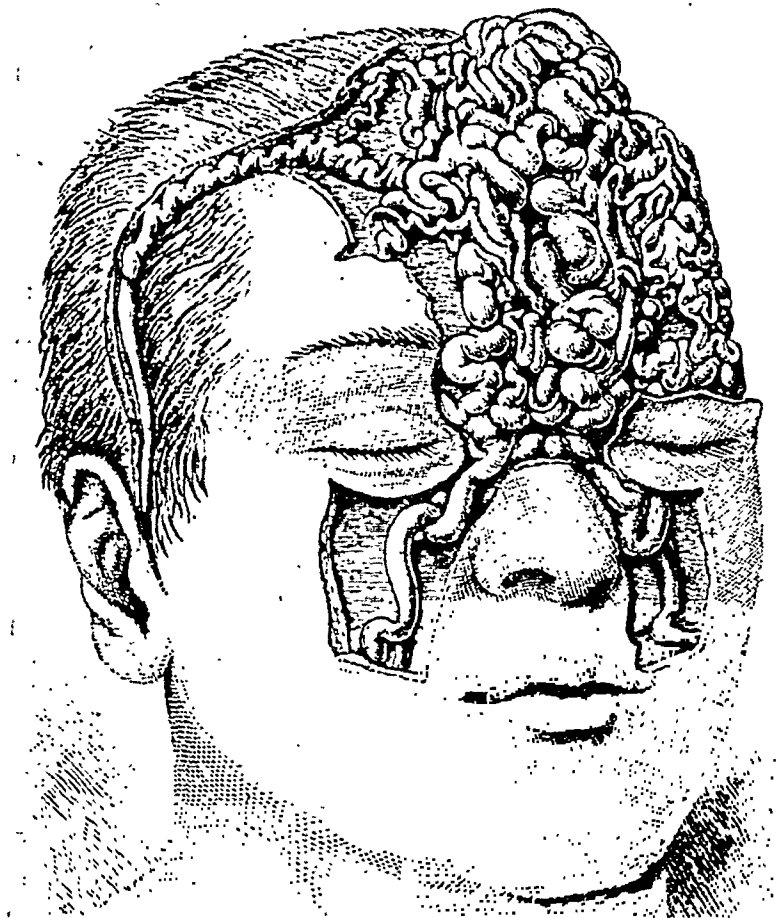


FIG. 1.—Case 1: Dissection of a cirroid aneurysm of the scalp (after H. Müller).

fully treated by a variety of methods—carotid ligation; multiple ligation of the lesion itself; obliteration with the galvanocautery; by the injection of thrombosing solutions; or by extirpation. The latter method is undoubtedly more certain of cure, and the method of choice.

All of these patients were treated by a similar operative procedure. As a preliminary step in the operation the principal artery or arteries, leading to the lesion were independently ligated. A flap of scalp, horseshoe in shape, was turned down in order to expose the lesion from the underside. In making this incision care was taken to include the galea in the flap. In other words, the incision was carried down to the pericranium and all tissues superficial to that were reflected with the lesion. Hemostasis was obtained by finger pressure and by individually ligating and dividing each vessel as it was encountered in

the incision. The main vessels, including the central portion of the lesion, were completely excised from the underside of the flap, particular care being taken not to button-hole the skin. After excision of the lesion, the flap was replaced with interrupted stitches of silk in the galea and in the skin.

#### CASE REPORTS

*Case 1.—Laceration of the scalp sustained in 1932. No symptoms until 1943 when large veins were noted on scalp and forehead. Preliminary ligation of right superficial temporal artery. Excision of cirsoid aneurysm on April 12, 1944. Recovery.*



FIG. 2.—Case 1: A. Preoperative appearance of the lesion.  
B. Appearance after extirpation of the aneurysm.

This 33-year-old soldier sustained a laceration of his scalp in 1932. The wound was sutured soon after injury. His course was uneventful until 1943, when he began to notice increased enlargement of the veins of the anterior region of his scalp and forehead. During this time he was occasionally conscious of "roaring sound" in his right ear. He was admitted to Ashford General Hospital on April 10, 1945.

Examination on admission revealed a small scar in the right parietotemporal region. Near this there was an elevated area 2 cm. in diameter, and from this region three greatly dilated vessels coursed down the scalp (Fig. 2-A). There was a well-defined continuous bruit and thrill over this area, which could be obliterated by occlusion of the right superficial temporal artery. Examination was otherwise normal.

On April 12, 1944, operation was performed. Through a small transverse skin incision the right superficial temporal artery, which was greatly dilated, was ligated and divided just in front of and slightly above the ear. A skin flap, with the base at the top of the skull and its outer margin just inside the hairline, was then turned back (Fig. 2-B). As the incision was made, numerous large arteries and veins were encountered just superficial to the galea. These were controlled by finger pressure until they were isolated and separately ligated and divided. The main mass of vessels comprising the aneurysm was then dissected free from the underlying galea (Fig. 3). The galea and skin were replaced



with interrupted sutures of silk. His recovery was without event and he was returned to duty.

Examination one year later showed no evidence of recurrence.

**Case 2.**—*Scalp wound from small shell fragment June 20, 1944. In January, 1945 patient first noticed swelling in the right temporal region with headaches and throbbing sensation in the right side of the scalp. Ligation of right superficial temporal artery. Excision of cirroid aneurysm of scalp on April 10, 1945. Recovery.*

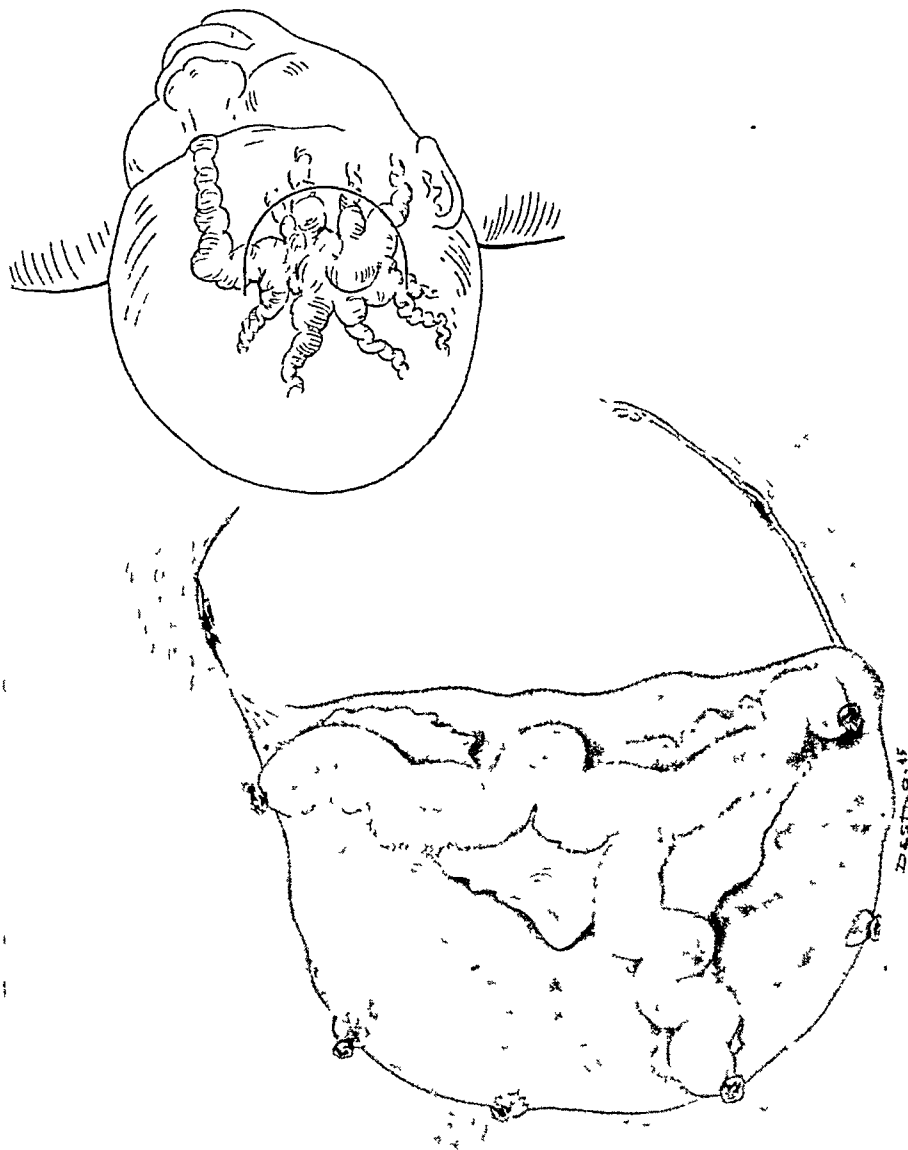


FIG. 3.—Case 1: Operative sketch. The flap has been turned back; the galea opened exposing the aneurysm.

This 27-year-old soldier was wounded on June 20, 1944, by a small fragment from a high explosive shell. There was only slight bleeding and he continued on duty. Due to another wound he entered the hospital on January 10, 1945, and at that time he noticed progressive headaches with a throbbing sensation in the right temporal region. At the same time he noted a pulsating mass just above the right ear. He was admitted to Ashford General Hospital on March 31, 1945.

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On examination, no scar could be found in the scalp. There was a pulsating dilatation in the region of the right temple (Fig. 4-A). A definite thrill and a continuous machine-like bruit, accentuated in systole, could be heard in this region. Both the bruit and thrill could be obliterated by occlusion of the right superficial temporal artery. With this obliteration the pulse rate fell from 88 to 80 per minute. Physical examination was otherwise normal.

On April 10, 1945, operation was performed. Through a small longitudinal incision just in front of the upper portion of the ear the superficial temporal artery, which was greatly dilated, was ligated and divided. A skin flap including the galea, with its base just above the ear was then turned down (Fig. 4-B). Numerous dilated vessels were isolated, ligated and divided as the incision was made. The vessels within this flap were then dissected from the tissue between the galea and the skin, and completely removed (Fig. 5). The flap was replaced with interrupted sutures in the galea and the skin.

His recovery was uneventful and two months later there was no evidence of recurrence.



FIG. 4.—Case 2: A. Appearance of the lesion before operation.  
B. Postoperative photograph showing incision.

**Case 3.**—*Scalp injury without laceration in 1937 followed by a small pulsating tumor. No increase in size of lesion for eight years until a second injury without laceration was sustained over tumor mass. Immediate increase in size of tumor with appearance of large dilated vessels over the scalp. Ligation right external carotid artery, left occipital artery, left superficial temporal artery and resection of cirsoid aneurysm on May 8, 1945. Recovery.*

This 25-year-old soldier suffered an injury to the right parietal region in 1937, when he was struck on the head by a fist during an altercation. Following this a small pulsating hematoma, 0.5 cm. in diameter, developed which gave him no trouble. On March 12, 1945 while in combat training he was accidentally struck on the right side of his scalp by the elbow of his opponent. Three hours later he noticed that the mass was considerably increased in size, although it was not painful or tender. Within the next month the swelling increased rapidly and he became conscious of a discomforting pulsation in his



FIG. 5.—Case 2: A portion of the vessels removed at operation.

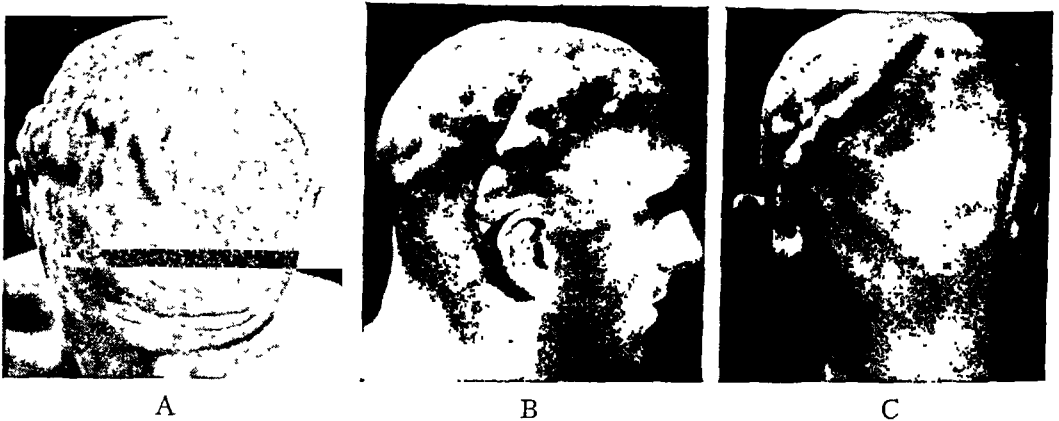


FIG. 6.—Case 3: (A, B, C.) Condition before operation, May 8, 1945.

scalp, and a throbbing, buzzing sensation in his left ear. He was admitted to Ashford General Hospital on April 23, 1945.

On examination, a large tortuous system of convoluted blood vessels covered the whole right side of his scalp (Fig. 6-A, B). The main tumor mass was centered in the right parietal region and the vessels which radiated to and from it were apparently derived mainly from both superficial temporal, frontal, and the left occipital veins and arteries (Fig. 6-C). From the central tumor in the right parietal region vessels radiated over the entire scalp. These appeared to be venous and were readily compressible, although all of them pulsated. Over the right parietal region a harsh, continuous bruit and the

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thrill could be heard. The bruit was transmitted throughout the scalp but was readily obliterated by pressure of the right carotid vessels in the neck.

Operation was performed on May 8, 1945. Preliminary to excision of the aneurysm the right external carotid artery was ligated and the left occipital and left superficial temporal arteries were ligated and divided. A horseshoe-shaped incision, with its base



FIG. 7-A

FIG. 7.—Case 3: (A) Operative sketch showing incision of galea and extirpation of aneurysm.

above the right ear, was then turned downward (Fig. 8). The incision was carried through the galea and numerous large tortuous vessels were ligated and divided as they were reached. The galea was then opened and a mass of dilated vessels removed from the underside of the flap (Fig. 7). In spite of previous ligations there was considerable bleeding during the operation which was controlled by sutures and coagulation. The flap was replaced by suturing the galea and skin with interrupted sutures of silk.



FIG. 7-B

FIG. 7.—(B) Portion of the vessels removed.

Recovery was uneventful and three months after operation there was no evidence of recurrence.

**Case 4.**—*Congenital nevus of right ear noted for ten years. Discomfort and throbbing in the right side of the scalp first noticed in February, 1945, together with the presence of large dilated vessels. Progressive enlargement of right ear. Ligation of right superficial temporal artery. Excision of cirroid aneurysm of right side of scalp on June 8, 1945. Excision of hemangioma of right ear on July 14, 1945. Recovery.*

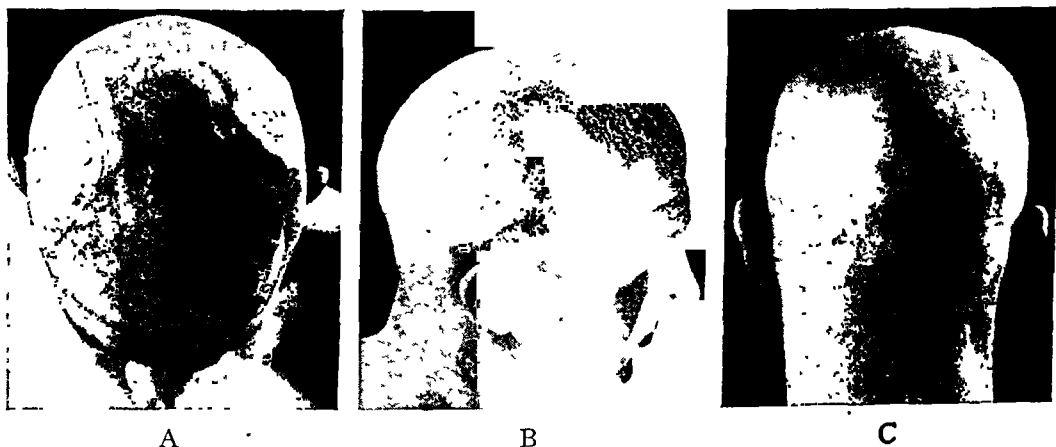


FIG. 8.—Case 3: (A, B, C)—The head has been shaved to show appearance two months after operation. The dilated vessel in the parietal region is thrombosed.

## CIRSOID ANEURYSM OF SCALP

This 20-year-old soldier recalled that his right ear had been larger than the left for the past ten years and that it had always been warmer and darker in color than the opposite ear. He was inducted into the Army in May, 1943, but it was not until February, 1945 that he became aware of discomfort and throbbing of the right side of his forehead particularly when wearing a helmet. At this time he first noticed the presence of large dilated vessels above the right ear and the apparent increase in the size of the ear. There was no history of injury except that which could possibly be attributed to the wearing of a helmet. For this he was admitted to Ashford General Hospital on April 28, 1945.

On examination, there was a marked asymmetry of the ears. The left was normal, but the right was considerably enlarged. The soft tissues were thickened and were of a



FIG. 9.—Case 4: (A) Appearance of the lesion before operation.  
(B) Appearance one month after operation.

deep purplish-blue color. The inner side of the ear showed a considerable degree of fine telangiectasia. On the upper rim of the ear there was a definite "port-wine" discoloration with a number of small and large dilated vessels passing from this region to the right side of the scalp where there were numerous large, tortuous and dilated vessels. These apparently communicated directly with those of the ear (Fig. 9-A). Upon lowering the head the veins over the whole side of the scalp became greatly dilated. The mass of vessels above the right ear pulsated faintly and over them a continuous bruit, accentuated in systole, and of moderate intensity could be heard. The bruit and thrill could be obliterated by pressure over the right carotid vessels. It was believed that this cirroid aneurysm of the scalp originated primarily from a congenital nevus of the ear upon which continuous, although light, trauma had been superimposed.

Operation was performed in two stages. On June 8, 1944 the cirroid aneurysm of the scalp was removed. The superficial temporal artery and vein were ligated and divided as a preliminary step in the procedure. A horseshoe-shaped flap of scalp including the galea was turned down with the base placed just above the ear (Fig. 9-B). Numerous dilated

vessels were ligated and divided in making the incision. The galea was then opened and beneath it a large number of tortuous vessels were removed. The galea and skin were replaced with interrupted sutures of silk.

On July 14, 1945 the hemangioma of the ear was removed. An elliptical incision made just outside the hemangioma was carried down to the cartilage and all tissue discolored by the hemangiomatous mass was removed. One large communicating vessel from the scalp was ligated and divided. The skin on the posterior aspect of the ear was mobilized, which permitted closure of the skin (Fig. 9-B). Hemostasis was obtained by hot compresses and coagulation. The skin was closed without tension with interrupted sutures of silk.

He recovered from the operation without difficulty, and three months later there was no evidence of recurrence.

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# THE MANAGEMENT OF ANEURYSMS OF THE LOWER EXTREMITIES\*

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ARTERIAL ANEURYSMS of the lower extremities are frequent complications of arteriosclerosis. Theis<sup>1, 2</sup> has shown that arteriosclerotic aneurysms of the popliteal artery cause claudication and other symptoms of arterial circulatory insufficiency, and undoubtedly many of the circulatory complaints of arteriosclerotics which are attributed to "hardening of the arteries" are actually caused by popliteal aneurysms which are not detected by the attending physician. When the arteriosclerotic individual develops symptoms of inadequate blood supply to the lower extremities, a careful examination of the femoral and popliteal arteries should be conducted. Simple palpation will reveal an aneurysm in many incidences, but in others the oscillometric tests described by Theis<sup>1, 2</sup> will detect arterial aneurysms which can not be palpated. The detection of such aneurysms is extremely important, because they represent the first step towards the development of much more serious complications. Hufnagel<sup>3</sup> has commented that "all aneurysms are progressive in nature, and, if untreated, lead to disaster." Theis<sup>2</sup> is of the opinion that "injudicious conservative treatment will prolong the disability and increase the danger of thrombosis and the possibility of the thrombus extending into the collateral vessels, with resulting gangrene." Keynes and Morel<sup>4</sup> have pointed out that many small popliteal aneurysms are overlooked, both at the examining table and at the autopsy table. They feel that such undetected aneurysms constitute a special danger, because motion of the knee dislodges clots from them and causes spontaneous gangrene.

As the atheromatous process develops, the popliteal artery is constantly subjected to the trauma caused by bending the knee, and, as a result of these repeated angulations, the diseased intima is ruptured, medial degeneration occurs, and an aneurysm develops. If such an aneurysm is neglected, sudden blockage of the popliteal and anterior tibial arteries will occur at an unpredictable time. Blakemore<sup>5</sup> has emphasized the fact that the possibility of gangrene is ever present, because of the danger of thrombosis or rupture of the aneurysm. Wells, Coburn and Walker<sup>6</sup> have stressed the "near hopeless" outlook in the untreated case of popliteal aneurysm, and have urged that such lesions be repaired before complications develop. Flemming<sup>7</sup> advocates elective surgery upon proven cases of popliteal aneurysms, because he believes the chances of survival of the extremity are much better under these conditions than when spontaneous occlusion occurs.

According to Arnold Henry,<sup>8</sup> during the third century, A. D., a Roman

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surgeon named Antyllus, described his method of tying the artery above and below the aneurysmal sac, opening it and packing the empty cavity. Since that time various surgical approaches have been advocated for the treatment of arterial aneurysms. (Power<sup>9</sup> credits Richard Wiseman with having successfully ligated two ruptured popliteal aneurysms in elderly individuals during 1672, one hundred years before the classical work of John Hunter.<sup>10</sup>)

In 1888, Matas<sup>11</sup> performed the first endo-aneurysmorrhaphy, and his procedure has been accepted as standard technic since that time. The Matas obliterative endo-aneurysmorrhaphy is still the procedure of choice in carrying out the surgical treatment of arteriosclerotic aneurysms of the popliteal artery. The results which he has reported<sup>12</sup> probably never will be excelled. In his series of 103 cases of aneurysm of the popliteal artery operated upon by this technic, 93.6 per cent recovered with good function; there was one death, and only six cases of gangrene. These brilliant results are attributable to Doctor Matas' zeal and patience in laboriously building up a collateral circulation capable of supplying an adequate amount of blood to the extremity before surgery was undertaken. He accomplished this by the use of his special clamp, with which he applied intermittent occlusive pressure to the artery above the aneurysm. Doctor Matas always emphasized the importance of preparing these cases for surgery by patiently developing an adequate collateral blood supply. He has placed great stress upon the importance of conducting careful examinations to make sure that collateral blood supply was adequate before surgery was undertaken.

Keith and Horton<sup>13</sup> made a study of intermittent claudication associated with arteriosclerotic lesions, and came to the conclusion that "from the clinical and therapeutic standpoint, the chief problem involved in this type of case is to build up an adequate collateral circulation in the involved extremity as fast as is possible." They concluded that "any measure which will produce vasodilatation is worthy of trial."

Mulvihill and Harvey<sup>14</sup> experimented upon dogs, and showed that the fall in temperature caused by the ligation of the femoral artery could be avoided by performing a sympathectomy as a preliminary procedure. Theis<sup>15</sup> also carried out experiments upon dogs, and proved the value of sympathectomy as a procedure to improve the blood supply of an extremity. Flothow<sup>16</sup> reported 12 cases of elderly arteriosclerotic individuals with vascular insufficiency, whose circulation was materially benefited by alcoholic injection of the lumbar sympathetic trunk on the involved side. He was able to increase the temperature of the involved extremity by as much as 8° C. by interrupting the sympathetic nerve supply. Lilly<sup>17</sup> has reported similar experiences.

In 1933, Gage<sup>18</sup> first applied this knowledge to the treatment of aneurysms. He performed a right lumbar sympathetic ganglionectomy upon a patient who had a large, mycotic aneurysm of the right common iliac artery, and subsequently he was able to ligate the common iliac artery with no evidence of impaired circulation. In 1934, Bird<sup>19</sup> applied the same principle in the surgical treatment of an arteriosclerotic popliteal aneurysm, with equally gratifying

results. He attributed Doctor Matas' excellent results to his careful building up of a collateral circulation by using the Matas mechanical compressor. He felt that the use of this compressor involved some risk, because of the danger of creating an emergency by rupturing a diseased vessel. For this reason, and because the use of the Matas clamp required a long period of preoperative preparation, he advocated the employment of sympathetic ganglionectomy as a means of developing a collateral circulation safely and quickly. In 1939, Leriche and Froehlich<sup>20</sup> performed a right lumbar sympathetic ganglionectomy because of an occluded aneurysm of the femoral artery; they reported excellent results. In 1940, Gage<sup>21</sup> reported 15 cases of aneurysmorrhaphy done at the Tulane Clinic; preliminary sympathectomy was done in all of these and all of them were successful. In 1942, Richards and Learmonth<sup>22</sup> performed a right lumbar sympathectomy upon a patient with a popliteal aneurysm. Five days later the aneurysm was excised, and postoperatively the foot on the involved side was warmer than the other one. In 1943, Gage<sup>23</sup> in discussing the management of traumatic arterial aneurysms, advocated performing a sympathectomy to develop collateral circulation before obliterating a major vessel. He gave the following reasons for advocating this procedure: Vaso-spasm is overcome; vasodilatation is obtained; the capillary blood volume flow is increased; blood flow is increased in the distal segment of the artery; the caliber of the vaso varosum is increased; lymphatic flow is increased, and gangrene is prevented. He concluded that sympathectomy was more advantageous than the Matas' clamp because of the speed and thoroughness with which collateral circulation could be developed by sympathectomy.

The following cases are reported to show the value of sympathetic interruption as a method of establishing collateral circulation before undertaking surgery upon aneurysms of the lower extremity:

**Case 1.**—No. 1235: This 70-year-old white male had been aware of a pulsating mass behind the right knee for three years. He had called it to the attention of his family physician, who advised him that it was nothing serious and to forget it. One morning he spent about 30 minutes squatting on his haunches, working on the motor of his refrigerator; when he attempted to stand he experienced an excruciating pain in the right calf and foot. He could not stand and had to hop to his bed. Subsequently, he spent several hours massaging the foot and calf. Six hours after the injury he called a surgeon, who found a cold, wax-like limb, and amputated in the mid thigh. Postoperative examination of the amputated limb showed a large, arteriosclerotic aneurysm filled with a recent clot which extended down to the ankle and up to the site of amputation.

This case is presented as being typical of the usual course of arteriosclerotic popliteal aneurysms. Had this man been operated upon prior to his accident, there would have been an excellent chance of saving his limb. He now is developing a similar lesion in his remaining limb, and plans have been made to perform a sympathectomy and endo-aneurysmorrhaphy.

**Case 2.**—No. 1061: This 72-year-old man first presented himself on April 4, 1944, with a cold, painful, numb right lower extremity. For seven years he had noticed an orange-sized, pulsating mass behind his right knee. His medical doctor had told him that this was a normal condition and nothing to worry about. For two years he had

noticed the same type of lesion back of his left knee. For the past four months he had experienced cramps in the right calf muscles when he walked for more than a block. The day before he sought medical aid he went fishing and rowed a boat; he braced his feet on the seat in front of him and rowed with his knees in hyperextension for 30 minutes, and he then experienced a severe pain in the right calf. Shortly thereafter he observed that his foot had become cold and white. The extremity would not support his weight, and became numb. His physician injected morphine and applied heat. The condition persisted through the night, and the following morning the great toe had a purplish hue. He was hospitalized. Examination revealed a tender, hard, nonpulsating mass about 10 cm. in diameter, situated back of the right knee. A pulsating aneurysm of equal size was encountered in the left popliteal space. Two cubic centimeters of alcohol was injected paravertebrally into the proximity of the lumbar sympathetic trunk at the level of the first, second, third and fourth lumbar spinous processes, according to a technic previously described by us.<sup>24</sup> The color of the extremity improved immediately and the pain was relieved. The next day the patient resumed his normal activities, with no complaint except a localized tenderness over the thrombosed popliteal aneurysm. He has had no further difficulty with the foot. The thrombosed aneurysm has remained hard, and the other aneurysm is growing slowly. He refuses to consider surgery on the left side.

This case is presented as another typical complication of popliteal aneurysm in which it would appear that loss of the limb was avoided by a chemical sectioning of the sympathetic nerve supply to the extremity. Evidently, this man has permanently obliterated his right popliteal artery with an organized thrombus. Such a case has been reported by Hodge.<sup>25</sup>

**Case 3.**—No. J. 80231: This 46-year-old Negro man came to the Jackson Hospital on December 14, 1944, because of pain and swelling in the upper right thigh. This swelling had begun to develop three days previously, with no history of trauma or infection. Examination showed a tender, pulsating mass in the upper one-third of the right thigh. The right thigh had a circumference of 71 cm., as compared with 52 cm. on the left. The Kahn was 4 plus. The foot and leg were cold, and there was no palpable pulse below the tumor mass. A diagnosis of false aneurysm was made. An alcoholic injection of the right lumbar sympathetic trunk was done, and the aneurysm was operated upon. Several quarts of clotted blood were removed and the femoral artery was found to be ruptured at its bifurcation. The artery was ligated. The foot became warmer than the left one, and in six days the man was walking without difficulty.

**Case 4.**—No. P. 662: This 67-year-old white male was admitted to the hospital, October 21, 1942, with a painful, numb, cold right lower extremity. Three months previously he had noticed a pulsating mass back of the right knee. His physician advised him not to worry about it. The mass gradually increased in size, and on the afternoon of admission he experienced a sudden, sharp pain in the calf. The foot became white and he was unable to bear his weight upon it. Examination showed a pulsating mass in the right popliteal fossa. A cold, white, pulseless foot with ecchymotic spots on the toes was encountered. It was decided that he had dislodged a clot from the aneurysm which had occluded his popliteal vessel at its bifurcation. An alcoholic injection of the right lumbar sympathetic trunk was done, and immediately the pain was relieved. The temperature and color of the foot improved. Three days later the aneurysm was operated upon. A large, arteriosclerotic aneurysm, partially filled with old and new clots, was encountered. An obliterative type of endo-aneurysmorrhaphy was done. The next day the involved side was much warmer than the other extremity. The patient was allowed to walk on the seventh postoperative day, and has had no difficulty since that time.

Alcoholic injection was used in Cases 3 and 4 because of the urgent need of immediate relief from vasospasm.

**Case 5.**—No. J. 94497: A 63-year-old colored man was brought to the hospital because of pain and swelling of the left knee. One month prior to admission he first observed swelling back of the left knee. The swelling increased rapidly and the patient found it impossible to extend the knee. Examination revealed a hard, pulsating mass in the left popliteal space, which was quite tender. The circumference of the left knee was 58 cm. The circumference of the right knee was 36 cm. The foot was cold and pulseless. The Kahn was 4 plus. The following day a left lumbar sympathetic ganglionectomy was done. This caused the involved foot to become warmer than the normal one. Two days later the aneurysm was operated upon. A large, false aneurysm was encountered. Three quarts of clotted blood were removed from the popliteal space, and a defect the size of a dime was found in the anterior aspect of the popliteal artery. When this defect was plugged with the finger the artery was found to be patent. It was felt, however, that it would be unwise to attempt to reconstruct this diseased vessel, especially since the vein was firmly adherent to the vessel. The artery and vein were doubly ligated and sectioned. The involved foot remained much warmer than the normal one. The patient walked on the third postoperative day, and went home in one week. He has had no more difficulty.

Four of these five cases were more than 60 years of age. All of them demonstrated marked vasodilatation following sympathectomy, in spite of their advanced arteriosclerosis.

*Conclusions:* The experiences of the author, as exemplified in the cases reported here, and the experiences of Gage,<sup>14</sup> Bird,<sup>15</sup> Leriche,<sup>16</sup> and Richards<sup>17</sup> would indicate that lumbar sympathetic ganglionectomy will develop adequate collateral circulation in a lower extremity quickly and thoroughly, and will enable one to perform surgery upon aneurysms of the lower extremity with comparative safety.

#### SUMMARY

Aneurysms of the popliteal artery are a frequent complication of arteriosclerosis. Such aneurysms, when neglected, will ultimately create a surgical emergency, either because of a propagating, occluding thrombus, or because of rupture. These emergencies frequently terminate in amputation. Such undesirable end-results may be avoided; first, by examining carefully all patients who complain of peripheral vascular impairment of the lower extremity, to detect the presence of an aneurysm; second, by performing a lumbar sympathectomy to establish adequate collateral circulation quickly and efficiently; third, by repairing the arterial defect by performing a Matas' obliterative endo-aneurysmorrhaphy.

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DISCUSSION.—DR. AMBROSE H. STORCK, New Orleans, La.: Some experiences at the Vascular Center at DeWitt General Hospital have a close bearing on several of the subjects just presented. I am sorry that Major Norman Freeman, Chief of the Vascular Section at DeWitt, could not be here to take part in this discussion.

In connection with the management of popliteal aneurysms presented by Doctor Lilly, the frequent possibility of successful restoration of the popliteal artery in operations for popliteal arteriovenous fistulae was demonstrated at the DeWitt Vascular Center. Repair of the popliteal artery was done in eight cases and was successful in six. Incidentally, in a series of 88 arteriovenous fistulas in various parts of the body, restoration was done in 21 instances, with failure in only three. Postoperative arteriograms were done to demonstrate patency.

A lateral approach to the popliteal artery, modeled after that used by Doctor Elkin for the exposure of the popliteal and tibial vessels, was used to advantage in several instances, either for the purpose of controlling the popliteal artery preliminary to its exposure by conventional posterior incisions or as the sole method of approach to popliteal arteriovenous fistulae. The advantage of the lateral approach is that it makes exposure

of the popliteal artery easier, particularly when the posteriorly overlying popliteal vein is large or is surrounded by scar tissue. In the restoration of arteries and veins in general, transverse or oblique suture is definitely superior to longitudinal suture, which latter reduces the diameter of the vessels. No anticoagulant therapy was employed in any of the restorative operations. Whenever possible, the accompanying vein was restored as well as the artery involved. The incidence of edema and easy fatiguability was found to be less when the vein was restored. Because of the observation that the performance of sympathectomy in conjunction with operations for aneurysms and arteriovenous fistulae led to functionally better results, it was increasingly customary to perform preliminary, simultaneous, or follow-up sympathectomies.

The rapid increase in size and surface extent following trauma to a cirroid aneurysm, as reported by Doctor Elkin, was likewise observed in one of our cases, a soldier who, while a prisoner of war, received a blow on an ear which was the site of a small cirroid aneurysm. Following the trauma there was rapid local increase in size of the lesion with spread to the scalp, mastoid region, and upper neck.

Doctor Pemberton's report on the successful repair of an aorta-vena cava fistula is paralleled by a quite similar case operated upon recently by Major Norman Freeman and me.

**Case Report.**—A 25-year-old soldier received a right upper abdominal and a spinal cord shrapnel wound on Okinawa on May 14, 1945. He was immediately paralyzed from the waist down. Celiotomy on the day of injury disclosed a large retroperitoneal hematoma. Thrombophlebitis of the right leg followed operation. Six weeks after injury a pulsating mass, with intense thrill, was noted in the upper abdomen. Studies at the time of admission to DeWitt General Hospital showed some evidence of renal impairment and greatly dilated veins over the abdomen. Cardiac examination showed minimal damage. Because of increase in size of the aneurysm and the development of gastrointestinal symptoms including vomiting, operation was unquestionably necessary and was performed on September 27, 1945.

**OPERATION.**—A right paramedian incision was made from the xiphoid to just below the umbilicus. On opening the peritoneum a large pulsating mass was found beneath the gastro-hepatic omentum. An attempt was made to visualize the vessels entering the pulsating mass by division of the gastrohepatic omentum, starting from the left and working toward the right. The common, cystic, and hepatic ducts were pushed forward by the pulsating mass which occupied the posterior right upper abdominal quadrant, extending from the diaphragm, across the midline, down over the surface of the right kidney and lateralward to the edge of the liver. Pressure within the mass was considerable, and at a point close to the gallbladder, where the thrill was most intense, digital compression caused cessation of the thrill. Pressure on the aorta just below the diaphragm obliterated the bruit and thrill and caused the sac to collapse. Even after practically complete division of the gastrohepatic omentum it was still impossible to visualize satisfactorily the exact extent and components of the arteriovenous fistula. A rubber catheter was placed around the aorta just below the diaphragm and fitted to a Bethune tourniquet. Since it was impossible to localize the point of communication between the aorta and the sac, the peritoneum and transversalis fascia were incised from within the abdomen just lateral to the midline anteriorly, and the transversalis fascia and peritoneum were reflected out of the left lumbar gutter. By this procedure the descending colon, the pancreas, the left kidney and the small intestine were reflected to the right. The retroperitoneal tissues over the lumbar vertebrae were thickened and edematous, with some discoloration of old hemorrhage. The aorta was again encircled by a piece of rubber tubing proximal to the origin of the left renal artery. With the proximal and distal aorta occluded and by careful dissection with scissors, the junction of the aorta with the sac was finally exposed and the aorta was then cut away from the sac at this location and the opening into the sac was digitally plugged. The opening in the aorta was about one-half inch in length and was closed by two running sutures. The vena cava distal to the sac appeared to be obliterated. The opening in the sac was closed with a running suture. The rubber tubing which had been placed around the distal aorta, the left renal artery and the proximal aorta was released, and a good pulsation was transmitted across the aortic suture line. There was no leakage. Two Penrose drains were inserted through a stab wound below the left costal margin, one extending to the space beneath the diaphragm and the other

down to the region just above the pelvis. The peritoneum was closed with interrupted No. 20 cotton and the rectus fascia was closed with interrupted steel wire sutures. The skin was closed with silk. During the operation the patient lost considerable blood and was given 3,000 cc. of blood and 2,000 cc. of glucose and normal saline. At the conclusion of the operation, which lasted for eight hours, the patient was in fairly good condition and within one hour the extremities were warm and pulses were easily palpable at the wrists.

Convalescence was stormy because of impaired kidney function for the first two weeks following operation. Good recovery, however, finally took place and the patient is up and about within the limits imposed by his spinal cord injury. The dilated abdominal veins which were present before operation have disappeared.

DR. CLARENCE E. GARDNER, JR., Durham, N. C.: In discussing Colonel DeBakey's paper I should like to report our experience with acute artery injuries in a General Hospital in England. These injuries were received by crew members of heavy bombers of the Eighth Air Force while on high altitude bombing missions over Germany. They were received in the hospital on an average of six hours after being wounded; it was usually an additional two hours before they came to the operating room.

During the course of one year we treated 863 wounds in 645 fresh Air Corps casualties. They were distributed as follows:

	Per Cent of Total	No. of Wounds	Complicated Wounds
Head and neck.....	20%	173	{ 25 cranial penetrations { 3 artery wounds, face and neck. 41 pleural or peritoneal penetration { 32 major artery wounds (5.4%) { 48 peripheral nerve (8.0%) { 183 compound fractures (21.2%)
Trunk.....	11%	96	
Extremities.....	69%	594	

There were 35 major arterial wounds, distributed as follows:

Number	Ligated	Sutured	Amputation	
			Immediate	Delayed
1 Common carotid.....		x		
1 Internal maxillary.....	x			
1 Costocervical trunk.....	x			
1 Subclavian (mediastinal).....	x			
2 Brachial (upper 3).....	x			
1 Brachial (at elbow).....	x			
2 Radial and ulnar.....		x	x	
1 External iliac.....	x			x
6 Femoral.....	x			x gas gangrene
	x			
		x		
			x	
			x	
			x	
2 Profundus femoral.....	x			
5 Popliteal.....	x			x gas gangrene
		x		x
		x		x
			x	
			x	
9 Posterior tibial.....	x			
3 Peroneal.....	x			
Total....35.....	24	5	6	5

Of the 35 injured arteries 24 were ligated, five were sutured and, in six, attendant damage to the extremity was so severe that immediate amputation had to be done.

In five cases gangrene subsequently developed and amputation was necessary; in

two cases because of development of gas gangrene. Incidentally, these were the only two cases of gas gangrene we saw, although we grew organisms of the clostridial group in 42 per cent of 177 cases in which freshly débrided tissues were cultured.

Gangrene of the foot developed in the one external iliac artery which was ligated and in the two popliteal arteries which were sutured.

From this experience we might conclude that under battle conditions ligation of most of the major arteries is a satisfactory procedure. However, in certain locations, notably in the popliteal and common femoral, possibly also in the brachial above the deep branch, some form of restitution of blood flow within the artery should be devised. In our cases the sutures seemed satisfactory except in the two instances of repair of the popliteal artery. Failure might be attributed to the fact that heparin was not available in either of these cases, or to the method used (Doctor Blakemore's vitallium tubes were not available), or to the fact that the time interval between wounding and surgery was too long in each case.

DR. BARNEY BROOKS, Nashville, Tenn.: There is too much experimental and clinical evidence for the possible beneficial effects of ligation of the concomitant vein in certain instances of arterial obstruction for this procedure to be discarded as unworthy of consideration. Any worth while evidence for or against the value of this procedure would have to be composed of a considerable number of instances, in each of which there was ample opportunity for a sufficiently careful analysis of the conditions to be sure that each instance was one suitable for test. I have previously emphasized that an occasion for a therapeutic venous occlusion for the prevention of gangrene is seldom encountered.

LT. COL. F. A. SIMEONE, Washington, D. C.: I should like to close this discussion by presenting a little more of an analysis of the factors affecting the results of the acute wounds of the arteries.

This slide indicates the results of attempts to aid the circulation by means of sympathetic block and sympathectomy. The incidence of amputation after sympathectomy was 71.4 per cent in 42 cases. After sympathetic block without sympathectomy, the incidence of amputation was 48.8 per cent. The figures suggest that sympathetic block improves the results while sympathectomy makes them worse. Actual experience with these cases provides a ready explanation for this paradox. Sympathectomy was done in relatively few cases of arterial injury. Indeed, it was often done only as a "last resort" when survival of the limb was thought to be unlikely—hence, the bad results. Sympathetic block, on the other hand, was done more often as a routine procedure after acute wounds of the arteries and the results are better.

This next slide shows the better results when the lesions were repaired by simple suture than when continuity of the vessel was reestablished by nonsuture methods. The results after nonsuture anastomosis are similar to those for the group as a whole. Better than average results can be expected after simple suture because cases in which this is possible usually have small wounds with little tissue destruction. Wounds for which a nonsuture type of anastomosis was necessary in order to bridge the gap in the artery were generally very extensive.

The next slide shows the effect of the time-lag from wounding to surgery upon the results of arterial injuries. The importance of this factor is obvious. The majority of cases were not operated upon until 12 or 15 hours had elapsed from the time of wounding and thrombosis may have occurred in the peripheral vessels. This fact, along with the extensiveness of the wounds, imposed serious limitations upon the practice of nonsuture anastomosis.



# PLASTIC SURGERY IN WORLD WAR I AND IN WORLD WAR II\*

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As there are a large number of men, wounded or injured, in World War II, who require plastic and reconstructive surgery, it may be timely to look into what is being done for these patients, and also to compare the present set-up with that used for the treatment of similar cases in World War I. As I am more familiar with plastic surgery in the army, my observations will be based principally on that service.

The object of military plastic surgery is primarily the restoration of function and comfort, and incidentally with the improvement of appearance.

When we entered World War I, there was total ignorance of plastic surgery in the army, but it must be said, that even in civil hospitals and medical schools of that time, 1917, the appreciation of this branch of surgery as a special subject was also totally lacking.

The tables of organization in the army failed utterly to make adequate provision for plastic surgery in World War I and repeated in World War II. Unquestionably, the first world war awakened general interest in the possibilities of plastic surgery, but few additions were made during this period to the basic principles of plastic surgery, which had been established long years before, although some of them were rediscovered and reported as new. As a matter of fact, there have not been any important new principles in plastic surgery developed so far in World War II, but simply better and more skillful use has been made of methods and principles previously devised.

In England, when the unexpectedly great number of maxillofacial wounds began to come in, in 1914, there was no one trained to take over these cases, as their ignorance of the importance of the subject was at that time as profound as ours, when we entered the war. In this emergency, Harold H. Gilles, an otolaryngologist, was assigned to this work, although he had not had any previous experience in plastic surgery. He collected a group of men around him, including dental surgeons, and at first, by trial and error, the wounded men were treated. Later, as experience developed, the maxillofacial cases to which his service was limited were segregated, because of the insistence of Sir Arbuthnot Lane, in a hospital at Sidcup, and splendid work was done. After our entry into World War I, a number of American medical officers, recruited from civil life, worked temporarily with Gilles at Sidcup and obtained valuable additional experience. Full advantage was taken of the knowledge thus gained, and our own wounded, requiring plastic reconstruction of the maxillofacial region, received in consequence excellent care when they began to appear for treatment. Several U. S. Army Centers were set up in France to which max-

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\* Read before the Fifty-seventh Annual Session of the Southern Surgical Association, December 4-6, 1945, Hot Springs, Virginia.

illofacial cases were supposed to be sent. One of these was Base Hospital 115 at Vichy, another was in Paris and a third was in Bordeaux. My impression is that these centers were largely used in preparing cases for evacuation to the United States, and that little or no definitive work was done in them. These patients were eventually sent either to General Hospital No. 11, at Cape May, N. J., or to General Hospital No. 2, at Fort McHenry, Baltimore, or to the Walter Reed Hospital, or to General Hospital No. 40, at St. Louis.

Marked progress was made in World War I in the treatment of fractures of the jaws, and in the repair of destructive wounds of the maxillae, by bone grafting and by adequate and ingenious prostheses, and these methods have stood the test of time and some have been improved upon in World War II.

There was also great opportunity to try autogenous cartilage transplants, and also isocartilage was used when the occasion presented and cartilage was available. The reported results were promising, and after the war, this work in France and England by military surgeons stimulated again further investigation of the use of autografts and also of isocartilage, both fresh and preserved. Other tissues such as fascia, fat, periosteum, mucous membrane and nerves were also transplanted when needed.

Probably, the most useful plastic procedure developed during World War I was the tubed-flap which was reported independently by Filatov, in 1916, in Russia and Gilles, in 1917, in England. Another useful procedure reported in 1917 was the Esser "inlay," which is the application of an Ollier-Thiersch skin graft on a dental compound mould to form the lining of a cavity. Some skin grafts and skin flaps were used, but very conservatively, particularly in regard to skin grafts, as compared with their lavish use in World War II.

In World War I, there were no definite regulations as to the treatment of burns, and each surgeon used his own judgment and individual methods. In World War II, on the other hand, a great deal of attention has been given to the treatment of burns, which have been very numerous. I will not go into details here, but will only say that a special committee of the National Research Council has been studying the question, and that much progress has been made, and burns are being better treated now than ever before. However, I do not believe that the final answer has yet been found. The main features in the most modern methods of treatment are the care of shock; the prevention of loss of fluids by nonadherent pressure dressings, infrequently changed; the prevention of infection; the acceleration of healing by skin grafting as early as possible; and adequate nutritional care with proper vitamins, *etc.*, as convalescence develops.

Artificial replacements of chins, noses, ears, eyes, *etc.*, were devised in World War I, and are still being utilized both for permanent use and for the interval periods between operative procedures. Research along this line has been largely done by men in the dental corps and by artists, who are especially skilled in moulding and coloring the various new materials now available.

After World War I, scant interest was taken in plastic surgery by the regular medical corps of the armed services, and there were no surgeons in

either of the services, who were especially trained for, or who showed any special ability to do this work. In fact, there was little official recognition of the scope and necessity of plastic surgery by the Medical Corps of either the army or the navy before we entered World War II, as the tables of organization show.

On the other hand, since World War I, in civil practice, great advances have been made in almost every aspect of the art of plastic surgery, and a voluminous additional literature has appeared. There are better methods of treating and dressing wounds and of combating infection. Improved technics have been developed in skin grafting; in flap shifting; in rotation and use of adjacent tissues, and in the handling and successful use of all transplantable tissues. Shaped cortical and cancellous bone grafts and cancellous bone chips are being frequently utilized in the repair of bone defects. Auto- and iso carved cartilage grafts and diced cartilage for support and filling are being used more freely and successfully than ever before. There is a better understanding of the utilization, in the final repair, of scar or scar-infiltrated tissues; in the use of relaxation incisions, Z-plastics, and gradual partial excisions.

A Subcommittee of the Division of Medical Sciences of the National Research Council on Plastic and Maxillofacial Surgery was appointed,\* and considerable study was given to the early care of wounds of the face and jaws by this committee, as it was realized from the experience gained in World War I that skilled early treatment within a few hours, if possible, after the wound was inflicted made a great difference in the length of hospitalization and in the ultimate outcome. In order to facilitate early treatment, officers and men in the medical department in the Combat Zone were supplied with equipment for rendering first aid treatment for maxillofacial injuries and were instructed how to use this equipment—in arresting hemorrhage; providing adequate respiratory air-way; securing temporary approximate reduction and fixation of bone fragments; and also to prepare the patient for safe transportation from the Combat Zone to hospitals in the rear, either in a sitting position or lying on a stretcher face down if there was any danger of obstruction in the air passages. Other points found to be important were: very conservative débridement of the face and hands; avoidance of packing facial wounds open; avoidance of removing any bone fragment with soft-part attachment; insistence on the early closure of facial wounds by men trained to do this work; and the early covering of all extensive denudations by skin grafting or flap shifting.

The first idea about utilization of plastic surgery in World War II was that there should be a large number of plastic and maxillofacial teams made up of a plastic surgeon and a dental surgeon, and that these teams should accompany troops to the Front, where they would give early plastic care to those requiring this service. A number of four- and six-week courses were given in different parts of the country to train men for this work. There were also two

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\* Chairman, Robert H. Ivy; John Staige Davis, Joseph D. Eby, P. C. Lowery, Ferris Smith, Brig. Gen. F. C. Fairbanks, and Col. Roy A. Stout.

or three three-month courses given in different clinics, which were very much better.

After a time, all of these courses were discontinued, as it was realized that most of the real plastic surgery, after early closure of face wounds at Evacuation Hospitals, should be done in the Zone of Interior, and that a comparatively few trained general plastic surgeons in Plastic Centers, with adequate assistants and necessary equipment, could handle the situation much more satisfactorily.

No one in authority had an idea that plastic cases would be nearly as numerous as they have turned out to be in both services, and for that reason, the facilities at first provided turned out to be quite inadequate.

In time, nine Centers in newly built Army General Hospitals have been designated for plastic work in the United States: the Valley Forge General Hospital being the first one assigned for this purpose on March 6, 1943, and the others were added as necessity arose. These are the Newton D. Baker General Hospital, Martinsburg, W. Va.; Wm. Beaumont General Hospital, El Paso, Texas; George W. Crile General Hospital, Cleveland, Ohio; H. D. Cushing General Hospital, Framingham, Mass.; Dibble General Hospital, Menlo Park, Calif.; Northington General Hospital, Tuscaloosa, Ala.; O'Reilly General Hospital, Springfield, Mo.; Valley Forge General Hospital, Phoenixville, Pa.; and Wakeman General Hospital, Camp Atterbury, Ind.

It is impossible to visualize, unless one has seen it, the great number of plastic patients at present in the nine army Plastic Centers in the United States. They run from 1,000 to over 1,700 beds on a single service, plus additional patients from the orthopedic and other surgical services. Many of these patients require multiple operations, and the operative schedule in some of the Centers runs from 18 to 25 each day. Some of these operations are performed under general anesthesia, some under local. All of them are based on the restoration of function, and none of them are of the purely cosmetic type. It is a thrilling and stimulating experience to see some of these Centers in action, and to observe the superb morale of the men and the remarkable results being obtained.

The ability, breadth of training, experience and understanding, and organizing capacity of certain of the Chiefs of the Plastic Service is far greater than that of others, and, in consequence, better planned and better executed plastic surgery is being done in some Centers than in others. It is to be hoped that, in due time, the work in all the Plastic Centers will be equally excellent, and I feel that this can be accomplished by having general plastic surgeons in charge, and by having a thoroughly competent consultant in plastic surgery to supervise all Centers. Then, by the transfer of those unequal to the job and by adequate supervision and proper standardization of basic procedures, the best results can be obtained.

The equipment, operating facilities, number of beds, number of assistants and nurses, *etc.*, is better in some of these Centers than in others, and several of them are badly overcrowded and understaffed. There has been consider-

able difficulty in supplying trained assistants at these Centers, as many men with plastic training have been assigned to other work, and it is not possible under the present organization of the Medical Corps to get them back. Every facility is being used in some of the Centers for graphically recording the wonderful series of plastic cases by moulonges, photographs, movies and drawings. In others, the equipment is poor and little interest is taken.

At the beginning of World War I, there were, with the exception of myself, no general plastic surgeons available in the United States. In France, there was Morestin. In England, no one was trained along this line, but since then the entire picture has changed, and there are now a number of excellent plastic surgeons in this country and in all other civilized countries. There are today very few class "A" medical schools where plastic surgery is not being taught, and also in nearly all great hospitals there are plastic services. The American Board of Plastic Surgery has been organized, and there are two flourishing plastic surgery societies in operation. In consequence, when plastic surgeons were called for in this war, many more trained men were available than there were in World War I.

In World War I, for the first time, sections representing various special fields of medicine and surgery were established in the office of the Surgeon General in Washington, and among these sections were facial-plastic and oral surgery. Major V. P. Blair of St. Louis was called to the Surgeon General's office to organize this service. He was ably assisted by Major Robert H. Ivy, of Philadelphia.

I urged, at that time, that the Division be expanded to include all cases requiring plastic reconstruction regardless of the part of the body on which the lesion might be, but could not put it over, as there was no appreciation of the necessity of general plastic surgery by those with the power to act. I again urged this expansion in World War II, and some progress has been made along this line.

In World War II, in the Surgeon General's office in the Surgical Consultants Division, there have been created branches in general surgery; orthopedic surgery, neurosurgery, ophthalmology, otolaryngology, radiation, transfusion therapy and chemical warfare. It has seemed strange to me that a consultant in plastic surgery was not also added to the list. I, personally, felt that the lack of a representative in the field of plastic surgery in this war, considering the great number of casualties requiring plastic reconstruction, was a mistake. In place of a consultant in uniform, several outstanding general plastic surgeons from civil life were appointed civilian consultants in plastic surgery during the last year of the war. These consultants were Drs. Robert H. Ivy, Jerome P. Webster and John Staige Davis.

An inspection trip was made of all the U. S. Army Plastic Centers by Dr. R. H. Ivy and Dr. J. P. Webster in April and May, 1945, and a very comprehensive report was sent to the Surgeon General with certain well-considered recommendations. Practically, no further use was made of these consultants. I am delighted to be able to say that within the last few weeks a

consultant in plastic surgery has been added to the Consultants Division of the Surgeon General's office. Now, even at this late date, it will be possible to have all Plastic Centers under central observation and direction by an expert.

There are certain army General Hospitals where there is, as there always should be, close coöperation between the plastic surgery section and every other surgical section in the hospital. In other hospitals, this coöperation is not evident, and, in consequence, the most effective care of wounded men cannot be carried out. Every surgical division of the hospital—neurologic, orthopedic, urologic, ophthalmologic, and general, at some time, needs the help of plastic surgery, and plastic surgery needs the help of every other division from time to time, so close coöperation is essential. Section or individual differences must be subordinated in order to give the wounded soldier the skilled care to which he is entitled.

The Dental Corps has an excellent organization, with active consultants, and is doing splendid work in its field. In most of the Plastic Centers, there is close coöperation between the plastic and dental services, and many of the problems of maxillofacial reconstruction are worked out together. The dental service is also invaluable in the construction of prostheses, plates, and various splints. However, it must be remembered that dental surgeons, with few exceptions, are not qualified to perform plastic operations, even on jaws, on account of inadequate general surgical training.

Many orthopedic cases are referred to the Plastic Service for the transplantation of soft-parts to fill defects, before orthopedic procedures can be carried out, and some of the results are astonishing.

In a number of the army Plastic Centers, following Dr. Sterling Bunnell's suggestion and demonstration, hand cases requiring reconstruction have been grouped, and under plastic and orthopedic surgeons assigned especially to this phase of the work, very gratifying results are being obtained, and many hands have been salvaged, and made into useful functioning members, which seemed beyond saving.

In World War I, it was soon found that segregation of the maxillofacial cases in special hospitals or wards was most important psychologically in caring for these mutilated patients, and this should always be done, if possible, and is being done in our army and navy with plastic cases of all kinds.

At the beginning of World War I, there were no books available on the subject of plastic surgery, and although there were chapters in the surgical "Systems," nothing practical was available for the guidance of the military plastic surgeon. Since then, a number of books have been written on the subject and on its various phases. The most recent contribution, written largely by Ferris Smith, is the *Manual of Plastic and Maxillofacial Surgery*, one of the military surgical manuals, gotten out by the Subcommittee on Plastic and Maxillofacial Surgery of the National Research Council. Another function of this committee, besides getting out the Manual, was to send recommendations to the Surgeon General in regard to improvements in the plastic and maxillofacial set-up in the army and navy. This was done at the early

meetings on several occasions, with absolutely no results. However, things have improved.

One of the most important advances in the care of the wounded in World War II is the rapidity with which they are evacuated from the field to the hospitals where every care can be provided, and this is particularly important in the evacuation of severe burns and severe facial injuries. Sometimes, this can be done by plane in the matter of a few hours, and men are frequently back in the United States within a few days. There are also a number of army hospital ships and trains to facilitate this evacuation.

The free use of plasma in this war has saved many lives, and the daily shipping of whole blood for use in those cases where plasma is insufficient is an added factor of safety to the seriously wounded. All of these advances in treatment are as advantageous to men requiring plastic surgery as they are to other types of wounded.

Vast improvement has been made in the methods of anesthesia, both general and local, since World War I, and these advances have been most helpful in military plastic surgery.

The psychologic handling of plastic patients requiring help along this line is also being very well done in some hospitals and is a potent factor in securing satisfactory end results. In fact, the maintenance of high morale in the plastic wards means everything to each individual man and also to all of the men as a group. Some of the surgeons know how to keep morale high, and in consequence, their general results are better and their wards are happier.

In plastic surgery in this war, as always, asepsis should be aimed at, as often with scant tissue available for the reconstruction, infection may destroy the chance of the desired repair. But in battle wounds, infections frequently follow in spite of every precaution. In these instances, the wounded man today has a much better chance than he had in World War I, as with the local as well as the internal use of the sulfonamides and with the free use of penicillin, infections are prevented, and many cases which would previously have been fatal are saved.

In the European Theater in World War II, the Chief Surgeon, Major General Paul R. Hawley, promptly appointed a full set of consultants, including the specialties. It was foreseen early that a great number of war casualties would require plastic reconstruction, and their care could best be met by central direction. The first consultant was Lt. Col. J. Barrett Brown, whose title was Senior Consultant in Plastic and Maxillofacial Surgery and Burns, and as his assistant, Major Eugene M. Bricker. Together, they visited and studied the British set-up in civil and military plastic surgery. Close association with free interchange of ideas was maintained with both British and American dental surgeons and also with general, orthopedic and neurologic services.

It was difficult to establish plastic surgery as an army specialty, principally because of the lack of plastic surgeons on the tables of organization. However, great progress was made with the full support of the Chief Surgeon.

The duties of the consultant consisted of placing personnel properly;

establishing Plastic Surgery Centers; in determining the extent of plastic surgery to be carried out in the E.T.O.; in controlling, sorting and evaluation of patients so that they would get into the proper hands; and in keeping in touch with the condition of patients when they arrived in the United States from E.T.O. The first Plastic Center in E.T.O. was established in December, 1942, at the 298th General Hospital, and on "D" Day, June 6, 1944, about 18 months later, there were ten functioning Plastic Centers in the United Kingdom where plastic, maxillofacial injuries and burns were treated. The purpose of these Plastic Centers was to treat early, and restore to duty promptly, those with minor injuries, and to evacuate to the United States as soon as possible all those more seriously injured, who could not be returned to duty in from 120 to 180 days.

These Centers were established within easy ambulance haul of the areas into which the patients were evacuated by air, water or hospital train, as it was important to get them into the hands of the plastic surgeons as soon as possible after injury.

On the continent, as the invasion progressed, there were 11 or 12 Plastic Surgery Centers in different hospital groups. Those of particular importance were at Liege and Paris. The one at Liege functioned as a Transit Center for air evacuation of plastic patients to the Centers in the United Kingdom. The two in Paris functioned for air evacuation of patients to the United States.

In the Mediterranean Theater, no permanent Plastic Center was set up. Temporary designations were usually established in one of the General Hospitals. The first one was in the 33rd General Hospital, at Bizerte. During the Italian campaign, there was such a Center, the 52nd Station Hospital, in Naples.

In the Pacific area similar arrangements existed toward the latter part of the war. In those areas throughout the world where special plastic facilities were not available, excellent work was done on plastic and maxillofacial cases by plastic and dental surgeons assigned to this work in different hospital installations, as allowed by the tables of organization.

In England, in World War II, Sir Harold Gillies, with his colleagues, has charge of all plastic surgery, and there are Plastic Centers at Basingstoke, Gloucester, Birmingham, Edinburgh, and probably other places.

All British maxillofacial casualties in the African campaign were segregated in a Center in Algiers, and in Italy a similar Center was set-up in Naples. Remarkably fine work was done on these patients, who were usually received within the first few hours after injury.

Little authentic news about the progress and practice of military plastic surgery in World War II has come as yet from either the Russian Medical Corps, or from the military services of the Axis countries.

In the navy, in World War I, there were not many plastic cases as compared with those in the army, and there was no special service organized for their care. In World War II, the same procedure was followed at first, as it was said that the Surgeon General of the Navy did not see the necessity of



a Plastic Section, and thought that any naval surgeon should be capable of doing plastic work. However, when a considerable number of men requiring real plastic reconstruction began to come in, this misconception was soon rectified, and with the help of a group of naval reserve medical officers, who were skilled plastic surgeons in civil life, several Plastic Centers were organized. In the Center at San Diego, California, under Capt. H. L. D. Kirkham, and his staff, who had been provided with fine equipment, large numbers of sailors and marines requiring plastic work are splendidly cared for. There are several other naval Plastic Centers, where excellent work is also being done, one at the U. S. Naval Hospital at Bethesda, Md.; another at St. Albans, L. I.; and another at the Oak Knoll Naval Hospital, Oakland, California. So the navy has also waked up to the importance of having plastic work done by trained plastic surgeons. In the September 1, 1945, J. A. M. A., the Surgeon General of the Navy reports that there were, during the week of August 22, 1945, a total of 796 plastic surgery patients in all of the naval Plastic Centers. From this, it can be seen that plastic surgery cases in the navy were not nearly as numerous as in the army, as in only one of the army Centers recently visited by me, there were more than twice the number of patients on that plastic service alone, than there were in all of the naval Plastic Centers combined. It is to be noted, that there is no special consultant in plastic surgery in the office of the Surgeon General of the Navy.

Now the war is over, what will be done with those men in Plastic Centers on whom plastic reconstruction has not been completed, and also with those who will require operative treatment over a period of years? The following are some of the questions asked about the subject: Will some of the present Plastic Centers be closed, and the patients concentrated in permanent military Centers? Will the treatment be continued as at present by trained plastic surgeons, from civil life, who are still in the army, or will the treatment be continued by medical officers from the regular corps? Will the army retain several trained plastic surgeons in the service to take care of these patients in military hospitals? Will these patients eventually be assigned to civil hospitals under the care of recognized civil plastic surgeons? Will arrangements be made to have the long drawn out cases sent to army hospitals, not too far away from the homes of the released surgeons, who took care of them in the Plastic Centers while in the service? Will they be kept in military hospitals, and the operative work be continued by civil plastic surgeons, who have previously been in the army, employed on a contract basis? Will these patients be assigned to the Veterans Administration and will Veterans Administration surgeons take care of them? Will the Veterans Administration induce trained and competent plastic surgeons, either from those already in the army or navy, or from civil life to enter the medical section of the Administration to take care of plastic cases, if and when, they are transferred to that administration?

As a partial reply, I have been told authoritatively, that all plastic surgical cases will be kept in the army until their care has reached maximum benefit.

Also that the army has no intention of turning these patients over to the Veterans Administration until the Veterans Administration has facilities, which are comparable with those in which the wounded men are being treated.

In this connection, it may be interesting to note how plastic surgery is handled in Canada. The Navy, Army, Air-force and Department of Veterans' Affairs have joined to provide specialty surgery of all varieties. As far as plastic surgery is concerned, these joint service special treatment Centers are in Montreal, Toronto and Vancouver. The work of these units has been supervised by a Joint Service Advisory Committee to the directors of Medical Services of the Navy, Army, Air-force and the Department of Veterans Affairs. The joining of the active services with the Department of Veterans Affairs has worked out very well for specialty surgery. Now the war is over, the Department of Veterans Affairs is taking on skilled workers from the armed services, and the units will eventually no longer be combined service but completely Veterans Affairs.

There has been sharp criticism of the organization of the Army Medical Corps under Army Service Forces and of the Surgeon General's lack of authority. This matter has recently been ably editorialized by Loyal Davis and, again, by J. Earle Moore, and is a subject which all of us should be familiar with and be prepared to do something about before we forget it, and before another war comes around. Briefly, it is as follows: The Army Medical Corps is under the authority of the Chief of Army Service Forces. The Surgeon General is badly handicapped by lack of independence and by having little control of the disposition of his own corps, either in the United States or in foreign theaters. Units or individuals, once assigned, are out of his jurisdiction and under that of the Chief Surgeon of the Service Command or group where this assignment may be, still of course, under the Army Service Forces. The function of the Surgeon General's office is principally to obtain adequate personnel, to procure and distribute equipment, to supply hospitals, and to make recommendations. The Surgeon General is not a member of the General Staff and has no direct contact with it. It is interesting to know also that frequently before purely medical regulations can be put into effect, approval must be obtained from nonmedical officers of the Army Service Forces. When attention is drawn to these conditions, the usual reply is that the Medical Corps in World War II has done splendid work under the present system, so why change? Splendid work has been done, but the Corps, largely made up of well-trained men from civil life, has done its job on account of the ability of these men, in spite of the system, and not because of it.

#### SUMMARY

In World War II, American wounded service men, requiring plastic and reconstructive surgery, are getting admirable treatment by competent well-trained plastic surgeons; by splendid army nurses and by well-trained corps men.

Plastic cases are segregated in Plastic Centers. The equipment is for

the most part excellent. The prompt treatment of maxillofacial injuries and of all injuries requiring plastic reconstruction has made a great difference in length of hospitalization and in the ultimate result.

The early closure of facial wounds and the early covering of denuded surfaces by skin grafts or skin flaps has been found most advantageous. The treatment of burns is much more effective than ever before. There is a better understanding of the methods of combating shock and of the use of plasma and whole blood. Great advances have been made in building up plastic cases for operative work. The use of sulfonamides and of penicillin and other substances have prevented infections and have saved patients after infections have started.

There has been great improvement in the treatment of wounds of all kinds and in the methods of dressing wounds. There is better understanding of the handling of scar tissue. The methods of inducing anesthesia, and also of surgical technic has been improved along every line. New technics have been developed in the last few years in skin grafting and flap shifting, and, in fact, in all types of tissue transplantation, and all of these advances in knowledge are being constantly used. Another great advance is the marvelous improvement in the methods and speed of evacuating the wounded. Many more lives are saved than would have been possible in World War I, and better operative results are obtained.

Great advantage follows close coöperation between the plastic surgeon and the dental surgeon in the treatment of jaw injuries, also with the orthopedic, the neurologic, ophthalmologic and the general surgeon in their various fields. The psychologic handling of mutilated patients has been vastly improved.

The reconditioning program, with its various activities, also aids materially in helping many of the men back to a useful life. So it can be seen from this partial list that the wounded service man in World War II, who requires plastic reconstruction, is better cared for in almost every way than he was in World War I, and his chances of an excellent result are far greater.

The purpose of the Plastic Centers in the selected army and navy General Hospitals is to return the wounded man promptly to duty, or to civil life, with as normal function as possible, with the minimum of deformity and with his chin up.

I can do no better in concluding this paper than to quote in part a sentence from a letter recently sent me by Brigadier General Fred W. Rankin, Chief Surgical Consultant: "I know no finer contribution being made than your specialty is making." In other words, American Plastic Surgery is delivering the goods in World War II.

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PERSONAL COMMUNICATIONS

- Lt. Col. E. M. Bricker, M.C., A.U.S.
- Col. J. B. Brown, M.C., A.U.S.
- Col. E. H. Campbell, M.C., A.U.S.
- Major F. Clarkson, R.A.M.C.
- Lt. Col. M. E. DeBakey, M.C., A.U.S.
- Wing Comdr. A. W. Farmer, R.C.A.F.
- Col. R. H. Ivy, M.C., A.U.S.
- Capt. H. L. D. Kirkham, M.C., U.S.N.R.
- Vice Admiral R. T. McIntire, M.C., U.S.N.
- Brig. Gen. F. W. Rankin, M.C., A.U.S.

# USE OF CANCELLOUS BONE IN THE REPAIR OF DEFECTS ABOUT THE JAWS\*

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WHILE it is generally recognized that reconstructive surgery had its origin in antiquity, the practice of bone transplantation belongs to modern times and the use of bone grafts for remedy of defects of the mandible is a by-product of the first World War. Cole,<sup>13</sup> in a preliminary report in 1919, stated that in the first two years of the war only isolated attempts were made and that "occasionally active hostility was encountered." Between 1916 and 1922, however, fairly large series were reported by Lindemann<sup>31</sup> of Germany; the French group, headed by Délangeniére;<sup>15</sup> Cole,<sup>11, 12</sup> Bubb, and Tainter;<sup>50</sup> the group at Sidcup, headed by Gillies<sup>23</sup> and including Chubb, Fry, Risdon, Waldron, Blair, and Ferris Smith; Billington and Parrott<sup>4</sup>; Munby, Forty, and Shefford; Gallie and Robertson;<sup>20</sup> and Ivy,<sup>26</sup> who in 1920, gave a detailed summary of late results in the treatment of gunshot fractures of the mandible in the American Expeditionary Force. In the same year, Blair<sup>5</sup> made the statement that "no part of facial reconstruction received greater impetus during the war than bone grafting of the lower jaw." This was felt to be due to the establishment of close coöperation between the plastic and oral surgeon, working as a maxillofacial team, as well as to the availability of abundant material as a result of war casualties. From available figures it may be estimated that approximately 1,000 mandibular bone graft procedures were performed by workers in all countries, mostly for nonunion and for small losses of bone.

Between the two wars defects of the mandible requiring bone grafts were limited to sporadic cases, here and there, which resulted from severe traffic injuries, bullet wounds, osteomyelitis, and operative removal of neoplasms of the jaw. In 1927, for example, Ivy and Epes<sup>27</sup> reported a total of nine cases at Walter Reed General Hospital for the preceding five years. During this period Ivy had treated five additional cases successfully in private practice. With the advent of the "blitz" in Europe, however, incidence of mandibular fractures began to rise. In 1941, for example, McIndoe<sup>34</sup> reported ten bone grafts in 119 cases of fracture which occurred during a period of 15 months in 1939-40.

Statistical summaries of World War II casualties are far from complete, and few reports have been made in the literature as yet. It is obvious, however, that the incidence of massive maxillofacial avulsion wounds has increased out of all proportion to the number of casualties in a comparative study of jaw injuries in World War I. This may be due in part to the use of missiles of higher explosive action which produce greater shattering and loss of bone sub-

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stance. The survival of large numbers of patients with extensive injuries of the lower face results from careful training of aid men at the front line in the handling of such cases to prevent obstruction of air passages; by the routine use of plasma and blood transfusions in the early stages of injury; and lastly, by the early and prompt use of chemotherapy to prevent overwhelming local infection and generalized septicemia.

Much has been written in the last 25 years on the various aspects of bone grafting, particularly the theories of osteogenesis and the advantages and disadvantages of different types of grafts based largely upon these theories. It is not my purpose here to enter into the arguments on the intrinsic nature of periosteum, the problem of "creeping substitution" of bone grafts, the exact rôle of the osteoblast and the undifferentiated connective tissue cell in bone formation, or the effect of local tissue *pH* on the mineralization of preosseous tissue. For practical purposes, as pointed out by Ghormley,<sup>21, 22</sup> Murray,<sup>37, 38</sup> Arich and Austin,<sup>17, 18</sup> and Fry, and his coworkers,<sup>19</sup> we know from experimentation and from experience that healing following transplantation of bone occurs in much the same fashion as after primary fracture. Organization of a clot occurs in the graft bed, and there is invasion by organizing vascular connective tissue at a rate which is in reverse proportion to the density of the graft. After vascularization is established, bony absorption occurs to a certain extent, as evidenced by decreased density and, finally, there is redeposit of calcium and firm bony union. According to Wolff's law, there are changes in size, shape, and strength resulting from action of the attached and surrounding muscles and in response to mechanical laws of stress and strain.<sup>30</sup>

#### TYPES OF BONE GRAFTS

Sources of bone which have been employed in remedy of mandibular defects are, first, the jaw itself in the form of a sliding or pedicle graft for losses up to 3 cm. in the body or symphysis. Grafts from the tibia include cortical grafts, which are employed almost routinely for nonunion of fractures of the long bones, and thin shavings of bone about 2 mm. in thickness, the so-called osteoperiosteal graft, for relief of small defects which are unaccompanied by soft-tissue loss or distortion of contour. Grafts from the rib have been used on occasion and where the symphysis and overlying soft structures must be restored, clavicle grafts have been employed in pedicle flaps. During the past 20 years grafts from the ilium have become almost standard procedure, especially in the case of large mandibular defects and where there is marked contour deformity. All workers agree that the rapidity of "take" of a bone graft depends in a large measure on the amount of spongy or cancellous bone present, and the ilium furnishes an abundant and easily accessible source. From clinical experience it has gradually become apparent that neither periosteum nor cortical bone is necessary for the accomplishment of firm bony union. Cancellous bone, because of its soft, vascular nature, is more easily invaded by organizing connective tissue and may perhaps actually survive as living tissue.

One purpose served by cortical bone is in acting as a splint for bone frag-



FIG. 1-A



FIG. 1-B



FIG. 1-C

**FIG. 1.—Technic of Cancellous Bone Graft to Mandible:**

A. Exposure of fragments. Note the anterior fragment has been exposed only far enough to get good contact while the posterior fragment has been completely freed and is controlled during the operation by a wire through the angles. The cancellous graft is shown below the wound.

B. The graft is in contact with the lingual side of the posterior fragment which in this instance gave good facial contour.

C. Wound closed with two layers of continuous No. 38 steel wire. Note the subcuticular wire is extending from the skin and is to be tied over a gauze dressing before the pressure dressing is applied.

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ments in the extremities. In the jaw, however, immobilization is accomplished almost entirely by the use of mechanical appliances. For this reason it has been possible to employ grafts of pure cancellous bone from the ilium, and this procedure has been used routinely in the series to be presented. After careful

FIG. 2-A

FIG. 2-B

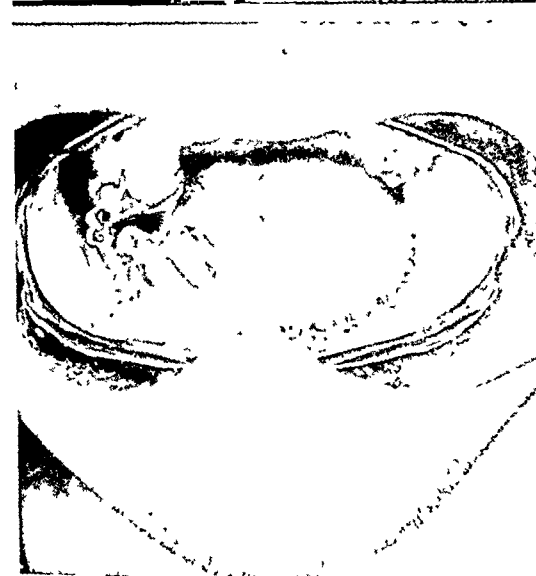


FIG. 2-C

FIG. 2-D

FIG. 2.—B. N. Pfc., age 24, received a machine gun bullet wound of the face with loss of the greater portion of the left body and angle of the mandible, 10 March, 1944. He was evacuated to this country as soon as his condition permitted and all drainage had subsided and sequestra were extruded by December, 1944. On 7 February, 1945 a large one-piece cancellous graft was placed over the defect and firm union with good contour has occurred. A stent graft was placed in the left buccal sulcus 1 October, 1945, and he now has good function.

A. Roentgenogram on admission showing large loss of substance on the left and nonunion on the right.

B. Flange cap metal splint to maintain the fragment in normal position during the waiting period and at the same time allow function of the jaw.

C. Interlocking cap metal splint, used for immobilization of the jaws.

D. Roentgenogram showing large cancellous bone graft in position.





FIG. 2

FIG. 2

FIG. 2-E

E. Contour of left face five months after bone graft.

F. Stent graft to create sulcus for denture.

G. Final denture before disposition.

removal of the cortex, the graft may easily be cut and shaped with heavy scissors or rongeurs, and successful results have been obtained in every case.

#### PLANS OF TREATMENT

The problems of definitive treatment of patients with severe deformities about the jaws requires close coöperation of the plastic surgeon and his dental consultant. After complete analysis of the defect from the standpoint of deformity and functional impairment, a detailed plan of treatment should be formulated and recorded with a statement of ultimate aims to be achieved and an approximate time schedule of operative procedures, stage by stage. Every effort must be made to help the patient make satisfactory adjustment, not only to his severe deformity but to the long periods of hospitalization and tedious waiting. Before surgery can be attempted he must be put in good general physical condition. Most patients with severe wounds about the jaws have suffered marked blood loss at the time of injury and show malnutrition and weight loss as a result of deficient diet. It has been our practice to restore normal weight and muscle tone by the use of high caloric diets supplemented by vitamin therapy and by the addition of large amounts of protein daily in the form of casein administered in milk shakes or malted milk drinks. Transfusions of blood and plasma are given where indicated until the patient's serum protein, blood volume, total blood count, and hemoglobin reach normal levels.

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To the dental surgeon is delegated the responsibility of immobilization of bone fragments, of treating infection about the mouth of dental origin, of designing temporary splints for the maintenance of fragments in the best possible position during the waiting period and splints for absolute immobilization in conjunction with the bone grafting procedure. In many instances, removal of loose sequestra in the region of the bony loss hastens the resolution of the

FIG. 3-A



FIG. 3-B



FIG. 3-C

FIG. 3.—E. G., S/Sgt, age 26, received a shell fragment wound of the left face, 13 September, 1944, with loss of bone about the angle of the mandible. He received a bone graft 19 June, 1945, approximately five months after the extrusion of all sequestra. At operation, the posterior fragment was completely liberated and held back in its normal position by a bar attached to the interlocking cap metal splint on the teeth.

A. Preoperative roentgenograms showing bone loss.

B. Extension bar attached to splint to keep the posterior fragment in position.

C. Postoperative roentgenogram showing onlay and inlay graft of cancellous bone.

soft tissue and stops drainage. Frequently fragments of teeth are out in the tissues and act as the source of chronic drainage from an area.

Soft-tissue deformities of the lower face must be treated adequately before any bone grafting procedures may be attempted. For large avulsion deformities pedicle flaps from the thorax and abdomen must be employed to give ade-

FIG. 4-A



FIG. 4-B



FIG. 4-C

FIG 4—H. S., Lt. Col., age 33, received a bullet wound of the jaw 14 January, 1945, with loss of a large portion of the symphysis and the right body of the mandible. The lower jaw was edentulous on admission and a large piece of silver wire was exposed in the mouth between the fragments. One month after admission the wire was covered spontaneously and the external wound was healed. At operation, 30 May, 1945, a large salivary cyst was encountered and removed. On removal of the silver wire the oral cavity was accidentally opened. Since the ilium was already exposed it was decided to place cancellous bone along the contour of the lost mandible and maintain the fragments by a perforated tantalum plate. Drainage from the wound was constant; however, on removal of the exposed tantalum plate, 18 September, 1945, firm bony union was found to bridge the defect.

- A. Preoperative roentgenogram.
- B. Roentgenogram showing tantalum plate and bone graft.
- C. Roentgenogram following removal of tantalum plate.

quate coverage. Less severe distortion of soft tissues may be treated by rearrangement of existing tissues. Even small distorted scars of exit or entrance we feel should be excised early in order to give complete relaxation of covering tissue (Fig. 6).

With confidence gained since the widespread use of penicillin, there has been a tendency toward earlier bone grafting than accepted practice has formerly dictated. In several instances bone grafts have been placed over defects within six weeks following the last noticeable drainage from the area (Fig. 4); in the majority of instances we have allowed at least six months to elapse in order for soft tissues to become more supple and a large part of the deep scar to become absorbed. It has been noted that the most satisfactory convalescence and earliest return to normal function and contour have occurred in patients who were prisoners of war for long periods of time following massive injury of the lower jaw. Our civilian consultants<sup>11, 51</sup> have reported that in England it is not unusual for a graft to be performed with chips of bone within three weeks after injury. Cuthbert,<sup>11</sup> for example, in 1944, reported the use of cancellous chip grafts in five cases as soon as the soft tissues healed after débridement and removal of fragments of loose bone.

#### METHODS OF FIXATION

The chief problem in individual bone graft procedures of the mandible concerns not the graft so much as the method of fixation and immobilization. This varies with the size of the bony defect, position and state of dentition of the upper and lower jaw and the fragments themselves. During the waiting period the fragments should be maintained in as normal a position as possible since, except in angle defects or edentulous fragments, it is almost impossible to change the position of the fragments at operation for fear of an opening into the oral cavity.

In symphysis or body defects with teeth on both fragments a cap metal splint with rigid crossbar is very satisfactory. At the time of the bone graft two interlocking cap metal splints will hold the jaws in absolute immobilization during the healing period (Fig. 6).

Where there is an edentulous fragment on one side of the fragment containing teeth is kept in normal occlusion by a flange splint, as shown in Figure 2(b). The other fragment not containing teeth is completely liberated at operation and replaced as nearly as possible to its normal position. After a long waiting period in these particular cases it is, as a rule, easy to expose and liberate all surfaces without fear of opening into the oral cavity. At operation, the edentulous fragment is maintained by a wire through the angle tip or ramus protruding through the skin and attached to a bar coming around the face from the intra-oral splint (Fig. 3).

In edentulous upper or lower jaws some modification of the Gunning splint is used during the waiting period and also in the healing period after bone graft. At operation in these cases we believe that some internal fixation is necessary and have used a piece of perforated tantalum shaped over an impression of a normal cadaver mandible (Fig. 4).

### OPERATIVE TECHNIC

The most satisfactory anesthesia for bone grafting procedures we feel is a high intra-oral mandibular block supplemented by 2 per cent novocaine for infiltration. Spinal anesthesia is employed, in addition, for removal of the iliac graft. Drapes are sutured in place to prevent slipping and accidental contamination.

In making the incision, care must be taken to prevent injury to the mandibular branch of the facial nerve. As a rule, it can be avoided by dissection downward external to the plastysmia about 2 cm. below the inferior border of the mandible before approach is made to the bone fragments. At least 2 cm. of each fragment is exposed when each contain teeth and no attempt is made to shift the fragments. In the case of a ramus, angle or posterior edentulous fragment exposure can be made by stripping the periosteum for long distances without fear of entering the oral cavity.

The edentulous fragment must be detached thoroughly to get it replaced in normal position. The eburnated ends of the fragment are cut off by a sharp rongeur and the outer cortex of the mandible is removed by dental bur until an area of bleeding bone sufficient for good contact is obtained.

In the meantime the iliac crest has been exposed subperiosteally by another surgical team. A large block of ilium is obtained with a sharp osteotome and placed on a wooden block for removal of all cortical bone, which is then discarded. The donor area is closed carefully in layers with interrupted silk, and a pressure dressing is applied.

Shaping of the cancellous graft is easily accomplished with sharp-cutting rongeur. All cancellous fragments are saved and are later packed into any open spaces in the graft bed or perhaps placed along the outerborder of the mandible to improve the general contour. The graft is shaped to act both as an inlay and onlay graft and is immobilized by a single strand of No. 32 stainless steel wire. At least 2 cm. should be in contact with the bleeding bone on each fragment. Although there may be marked protuberance externally at first, the transplant undergoes rapid absorption, and the contour of the mandible is quickly established after function begins.

Complete hemostasis is obtained by ligation of all bleeding points with No. 0000 silk. Closure is made in layers, and firm pressure dressing is applied. It cannot be emphasized too much that the wound must be closed without tension, and it may be necessary for this purpose to undermine the skin for a considerable distance to obtain proper relaxation. In over half of our cases closure was made with interrupted fine silk; but after we became convinced that drainage in two cases was the result of buried silk sutures, we began to employ a single removable stainless No. 38 wire for the deeper layers and continuous running stitch of the same material for the skin.

### POSTOPERATIVE CARE

Following operation, the patient is kept in a semisitting position, and careful attention is given to adequate air-way. In one instance it

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FIG. 5-A



FIG. 5-B

FIG. 5.—E. V. W., Pfc., age 30, received a rifle bullet wound of the face 14 September, 1944, with considerable loss of substance of the right body of the mandible. He had an edentulous upper jaw and was admitted for definitive treatment with an external pin fixation splint on the fragments. On 11 July, 1945, approximately three months after cessation of drainage, a large cancellous bone graft was used to bridge the defect using a modified Gunning splint for fixation. Excellent union occurred.

- A. Roentgenogram on admission.
- B. Roentgenogram after union.

was necessary to open the intra-oral splint for 24 hours to relieve obstruction. Liquid diet is given, and oral hygiene is maintained by frequent mouth wash, and careful daily inspection by the dental consultant. It has been our routine procedure to give the patient penicillin for five days, 20,000 units in one quarter per cent novocaine solution every three hours. Pressure dressings to both the donor area and the face are maintained for a period of ten days and, as a general rule, by 14 days patients have become ambulatory. Except for mainte-

FIG. 6-A



FIG. 6-B

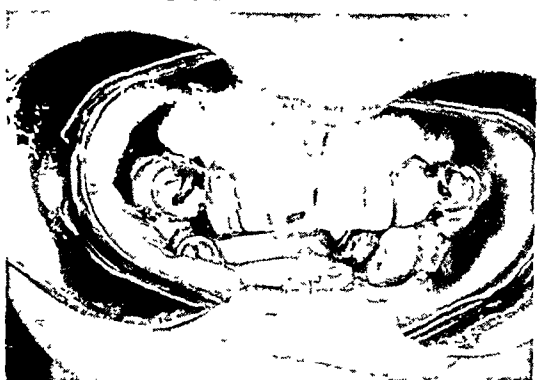


FIG. 6-C



FIG. 6-D

FIG. 6.—O. R. I., Pfc., age 21, received a shell fragment wound 29 June, 1944, with loss of considerable soft tissue of the chin and bony loss of symphysis and anterior half of right body of the mandible. The soft tissues were readjusted for better coverage 26 October, 1944, shortly after all drainage ceased and a cancellous bone graft was used to bridge the defect 20 March, 1945. The labio-alveolar sulcus was created by a stent graft 20 October, 1945, in order that a functioning denture could be used.

- A. Contracted cicatrices on admission.
- B. Roentgenogram showing bone loss.
- C. Interlocking cap metal splint for immobilization.
- D. Bone fragments exposed at operation.

nance of oral hygiene nothing further is indicated until seven to eight weeks have elapsed, at which time the cap metal splints are released and the state of clinical union inspected. If not absolutely rigid the splints are left on for another two to four weeks before removal. As soon as successful "take" is assured, patients are allowed 90-day furloughs. By the end of this period of time firm bony union has been obtained, and there is good contour of the jaw even in cases where considerable bulging was present following operation.

## BONY DEFECTS OF THE JAW

Dentures are fitted before furlough if possible. Otherwise when the patient returns, buccal and labio-alveolar sulci are reconstructed by stent grafts. Minor "touching-up" procedures are performed, such as alleviation of contour depressions by cartilage or derma-fat grafts. It has been interesting to note in some of these operations the condition of the bone graft which is necessarily

FIG. 6-E

FIG. 6-F



FIG 6-G

- E. Roentgenogram showing cancellous bone graft bridging the defect.
- F. Appearance following bone graft.
- G. Reconstructed labio-alveolar sulcus.

exposed. It is seen to be smooth and white with a well-formed periosteum; on stripping, many small reddish dots are seen as evidence of nutrient vessels.

### REPORTS ON CASES

During the past 16 months 457 patients have been admitted to the Plastic Surgery Section of our Center for definitive surgery of the upper and lower jaws, 339 with defects of the mandible. One hundred sixty-seven (167) were in a state of early union in good position on arrival and required prac-



tically no treatment except maintenance of oral hygiene, restoration of function by proper dentures and readjustment of soft tissue defect. One hundred and twenty-three (123), though ununited on admission were corrected by local measures alone. Of the latter, 24 had minimal bone loss but developed union with no severe functional loss or contour deformity. Five had loss of small



FIG 7-A



FIG. 7-B

FIG. 7.—J. P. P., Pvt, age 19, received a shell fragment wound of the face 24 June, 1944, with fracture of left mandible and maxilla. A cartilage graft was used 24 October, 1944, which was removed because of chronic drainage. On 7 June, 1945, a large cancellous bone graft was placed over the remaining portion of the maxilla, with good contour resulting.

A. On admission.  
B. Present contour.

amounts of bone in the angle region and obtained union following shifting of the ramus forward to compensate for the defect. Fifty-three (53) showed defects greater than 2 cm. and of these eight had extensive damage from avulsion of the soft structures in addition to bone, requiring replacement of the loss by pedicle flaps prior to bone grafting procedures.

At present, seven are waiting operation pending subsidence of infection and tissue reaction or in the process of repair of massive avulsion deformities. In three instances there has been considerable loss in the region of the ramus but all teeth are in occlusion and there is very little functional impairment so no bone graft is contemplated.

Forty-three (43) cancellous bone grafts from the ilium have been performed successfully to bridge defects of the mandible from 3 to 12 cm. in length. There has been drainage from the wound in eight instances; in two cases, attributable to buried silk; in two, the result of inadequate coverage; and in four, due to accidental opening into the oral cavity. Before the advent

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of chemotherapy it was recommended in all instances that bone graft be abandoned if the oral cavity should be entered. In one of our cases operation was postponed when this accident occurred because of the presence of a considerable amount of scar tissue. In the other cases no attempt at suturing of the opening was made since it could not be accomplished with sufficient relaxation of the tissues to prevent tension. Operation was allowed to proceed, and the area was drained for 48 hours. On two occasions the cancellous graft has been fractured because of too vigorous use of the osteotome in removal of the

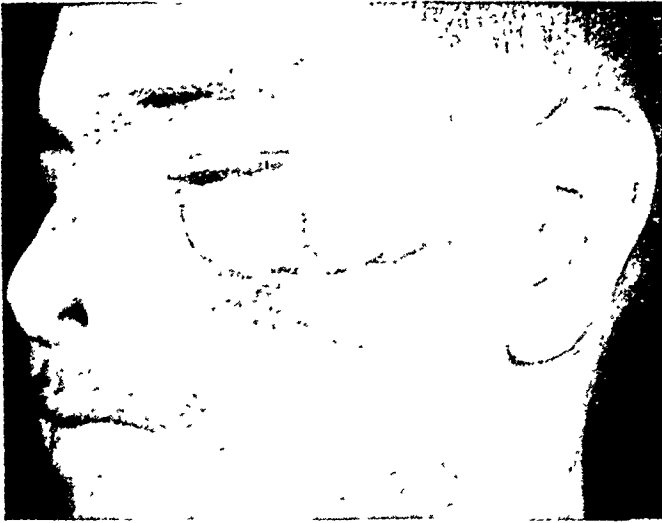


FIG. 8-A



FIG. 8-B

FIG. 8.—C. C., Pfc., age 19, received a shell fragment wound of the face 15 July, 1944, with avulsion of soft tissue and loss of the major portion of the left maxilla. The soft-tissue loss was replaced by pedicle skin and, on 10 August, 1945, the contour was restored by cancellous bone. It is believed that the majority of the pedicle skin can be removed by rotation of the neck skin over the area and the remainder improved by color implantation.

A. On admission.

B. Present appearance.

cortex. In each instance this has been spliced by placing a small cancellous chip on each side of the fracture and passing a single strand of No. 38 stainless steel wire through the fragments and chips. In each instance good union occurred without mishap.

Other complications of operation which should be reported are mild atelectasis in two instances and drainage of donor areas in two instances, one from buried silk and one from a small piece of rubber tissue.

In the case of the maxilla, 128 patients have been admitted for definitive treatment. Of these seven have had avulsion of considerable amounts of soft tissue in the malar region, upper lip, orbit, or nose. The majority have been treated by the use of cartilage grafts or by fitting intra-oral prosthetic appliances into artificial skin-lined cavities in the mouth produced by stent-grafting to restore proper contour. In nine cases, however, cancellous bone grafts have been employed. In one of these there was accidental entrance into the orbit, and an attempt was made to close over the opening. Although no drainage into

the orbit occurred, there was persistent drainage from the skin incision for three months.

### CONCLUSIONS

It must be emphasized that the treatment of bony defects of the jaw must be planned on a long-time basis of preparation for grafting by elimination of infection, removal of sequestra and broken fragments of teeth, and by remedy of soft-tissue defects before bone surgery can be attempted. Patience and time are the most valuable adjuncts to reconstructive surgery.

With the use of cancellous bone grafts from the ilium we have obtained successful "take" in 52 cases, 43 to mandible and nine to the maxilla, and we feel this type of graft is superior to other kinds of bone in repair of large and small defects of the mandible. The selection of a graft or the modification of technic is perhaps, in the final analysis, largely a matter of individual choice, and other workers may be able to show equal success with other procedures. However, we are all working to restore normal jaw function, to improve the patient's appearance as much as possible, and to achieve these results with as much dispatch as is compatible with safety.

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DISCUSSION.—CAPTAIN H. L. D. KIRKHAM, San Diego, Calif.: There is little that anyone can add to these three excellent papers. The hand problem has been terrific in both branches of the service. In some contractures, particularly in the web of the thumb, it is difficult in using a straight abdominal or chest flap to maintain the correct position of the hand. This can be accomplished very effectively by taking the flap from the opposite upper arm, which is grasped in the correct position by the affected hand and is thus in normal position. I obtained this from Colonel Barrett Brown at Valley Forge Hospital.

There is no question that the surgeon who has used cancellous bone and cortical bone would prefer cancellous. The comparison is about the same as fresh cartilage and preserved cartilage. At the Naval Hospital, San Diego, we used preserved cartilage entirely and had absolutely no trouble. The chief reason for this was that many patients complain more of the chest and ribs than of the wound itself, whereas if you go to the icebox and get preserved cartilage and slip it in there are no complaints.

There must be complete and full coöperation between the surgical and dental departments, and it is my feeling that the dental department should bear the same relationship to plastic repair as the bracemaker does to the orthopedist.

I would like to mention that we did have a couple of plastic cases in the Navy, too, although Doctor Davis did not mention the Navy.

COLONEL EDWARD D. CHURCHILL, Boston, Mass.: I must add a few words to Doctor Davis' scholarly presentation in regard to plastic surgery in World War II. When a missile strikes there are three factors that determine the size and shape of the resulting defect: First, the damage produced by the missile itself. Tangential hits and hits on the face may cause great mutilation, but these, fortunately, are unusual. Second, the complication of infection; particularly in the maxillofacial region, infection is one of the greatest factors in producing mutilation. Infection, however, can be controlled to a great extent, and I shall not attempt to discuss it, as you are all familiar with the great advance in this War in this respect. The third factor that may determine the size and shape of the defect is the surgeon. The surgeon can very easily increase the mutilation or defect by doing the wrong thing or not doing the right thing.

Doctor Davis used the term "general plastic surgeon"; I should like you to think for a moment about a "plastic general surgeon." There are not enough general plastic surgeons to treat all wounds nor even a large fraction of the civilian cases of malignant disease, which is a comparable problem. General surgeons must be familiar with plastic technics. If a lower extremity, for example, is struck tangentially, so that the resulting wound lies transverse to the axis of the extremity, it presents a neat little problem in general plastic surgery that must be treated by a plastic general surgeon. If an incision is made this way (indicating a crucial vertical incision), the defect is increased, perhaps to the extent that the soldier will never fight again. An incision made that way will create a stellate defect, and on the fourth day when the surgeon at the Base attempts to close the wound he is in trouble. If the initial incision had been made in this way (indicating), the soldier might well have returned to duty after six weeks.

The development and departure of the specialty of general plastic surgery has left a residual and mutilating defect in general surgery. Many general surgeons and specialists

in other fields of surgery limped into war with little knowledge of the technics and principles of plastic surgery. We knew too little about the skin as a living organ—about the tension it would withstand—about the gentle handling it requires. The simple principles of the Z-plastic, of the advancement or rotation of flaps, of the avoidance of “dog ears,” *etc.*, appear to be no longer matters of general surgical technics. The vicious bites of the rat-toothed tissue forceps added to the damage produced by the enemy.

So I propose the term plastic general surgeon in an attempt to compensate for the departure of the general plastic surgeon from our midst. We must save ourselves from the need of a consulting specialist when it is desired to do a “transcutaneous” operation.

DR. OSCAR L. MILLER, Charlotte, N. C.: Anything I say will not add to the scientific aspect of these papers, but I do want to make a few general remarks appertaining thereto. It was my privilege to make a few trips to certain army hospitals during the war. I wish to mention some of the things I saw. I saw the work of these young officers, Captain Shaw and Captain Payne, in the wards at Newton D. Baker General Hospital. You saw some of the results this morning. I want to express appreciation of the policy of the Surgeon General for segregation of plastic surgery, hand surgery, amputees and many types of surgery so they could be given the most expert care. It was then possible to take specialists from all branches of surgery who could in turn make experts of such young officers as these. Of the work of Doctors Davis and Blair—plastic surgeons—you know, and Doctor Brown was in the Army. All made their contribution, directly or indirectly, in the field of plastic surgery. There are still thousands of various types of plastic cases in the Army and hands are most difficult to reconstruct. You can appreciate why it is necessary for the Surgeon General to freeze some plastic surgeons as well as other specialists.

I may never have another such opportunity, and I want to take advantage of this one to pay particular respect to the conduct of the Surgeon General's office during this war. It may have had some shortcomings, but it will go down in history, in the minds of the medical profession and in the hearts of the people of this country, as a monumental success.

COLONEL DAVID H. POER, Martinsburg, W. Va.: I merely want to restate some points made by Captain Payne and Captain Shaw, concerning the intrinsic factors in reconstruction of the hand. I was afraid it might have been lost among their nice pictures.

With regard to reconstruction of the hand as a whole, it has been stated that this is the place where several specialists meet; the neurosurgeon, plastic surgeon, and orthopedic surgeon. The person who handles it must be trained in all three of these specialties; that includes the bones, which may require grafting or realinement, the tendons which may need lengthening or suture, or in many instances transfer to prevent loss of vital function; the joints which require plastic procedures, and the suture of small nerves and replacement of skin surface with adequate fat padding. I think some of the most remarkable results have been in those cases in which the tendon from one side of the hand is brought to the other, to restore some degree of function; and the suture of the small digital nerves. Those who attempt to do all these things must realize what it entails.

DR. EDWARD M. HANRAHAN, Baltimore, Maryland: I am sorry time did not permit Doctor Davis to finish his paper. It seemed to me to be a preview of what historians of the future will have to say about the development of plastic surgery during the first and second World Wars. Maxillofacial surgery developed markedly during the first War and Doctor Payne showed how plastic surgery of the hand has developed in this War. Up to this time we have had only two men, Bunnell and Koch, who knew very much about the hand. Now we are training a number of men. In past times the ordinary run of surgeons and hospitals might have one or two serious hand cases a year, but I believe that industrial accident insurance companies and industry in general will urge that badly damaged hands be treated in special Centers and handled by these men who have done such remarkable work in this War. The damage done to extremities, with contractures, and the damage to hands, has made surgeons use every ounce of ingenuity and apply every basic principle evolved before the War in treatment of these injuries. War does

not evolve new procedures; the tube flap was developed in 1916, and this has probably been the one procedure that has given increased stimulus to general surgeons and orthopedic surgeons in their treatment of hand and other injuries where more than a mere skin covering is necessary.

Recent years have seen the development of newer metals and metallic compounds, and these have come to play an important rôle in plastic surgery. The principles of this surgery remain the same and their application has been beautifully shown in the papers of both Doctor Payne and Doctor Blocker. As one listened to these papers one could not help but wonder what is going to constitute the plastic surgery of the future. Are we going to have hand specialists, maxillofacial specialists, or general plastic surgeons? Or will the field become so important that we will have plastic general surgeons as Doctor Churchill suggests? This field is in a very active phase of development and all who are interested are well conscious of it.

DR. DARREL SHAW, Martinsburg, W. Va. (closing): I would like to take this opportunity to thank Doctor Davis for the very clear picture he presented of the situation of plastic surgery in World War II.

Captain Kirkham mentioned the problem of contractures between the first and second metacarpals. I might mention that we have realized the difficulty in getting the thumb away from the hand and still maintain position and function. It is frequently necessary, in addition to the removal of dense scar tissue, to divide the fascia of the contracted muscles. Sometimes it is indicated to sever the insertion of the abductor to the thumb and divide the attachment of the first interosseous muscle. Even then capsulotomy of the carpometacarpal joint may be required. Doing these procedures we have had little difficulty in obtaining position and maintaining function where there is not too much loss of tissue. When this is true we have done tendon transplants for apposition after the method of Dr. Bunnell. Dr. Churchill mentioned a very common problem frequently brought to the attention of plastic surgeons handling cases treated elsewhere. It is certainly a point to mention, that the eventual plastic reconstruction should be considered by those doing early surgery. Even an ill-advised incision may greatly complicate the plastic reconstruction. The plastic surgeon, I believe, has contributed definite knowledge about handling tissues and the care of wounds by virtue of the difficulties with which he is frequently faced; dealing with tissue of low vascularity, and expecting to get a very nice result from a difficult procedure. The plastic surgical concept of early wound closure by suture or grafting has been popularized by this War.

DR. JOHN STAIGE DAVIS, Baltimore, Md. (closing): I would like to tell Captain Kirkham that the only reason nothing was said about the Navy was because of lack of time. I have a paragraph in my paper on the work being done in the Navy.

# MUSCLE-FLAP TRANSPLANT FOR THE RELIEF OF PAINFUL MONARTICULAR ARTHRITIS (ASEPTIC NECROSIS) OF THE HIP\*

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SAN ANTONIO, TEXAS

DEGENERATIVE MONARTICULAR ARTHRITIS of the hip joint is one of the most painful chronic conditions of late middle age, and the resultant disability "sadly embitters but does not shorten the duration of life."<sup>11</sup> Nubian workmen in 3500 B. C. were found to be afflicted with this condition and probably all subsequent generations of humans have suffered from the malady.<sup>21</sup> In the 19th century, Adams, of Dublin, suggested the name "morbus coxae senilis" which is still very apt.<sup>1</sup> Despite its antiquity and ubiquity, treatment of this condition has been unsatisfactory because no single method has ensured relief of pain.

*Etiology.*—Destructive arthritis of the hip joint in adults is often secondary to injuries or pathologic changes which in some way disturb the normal circulation to the head of the femur. Damaged bone is incapable of establishing collateral circulatory pathways anywhere in the body, but especially in the head and neck of the femur, only a minimal number of blood vessels are normally present.<sup>9, 19, 34, 35, 36</sup> Old contusions or fractures of the hip, traumatic dislocations, inadequately treated Perthes' disease or slipped femoral epiphyses are frequently followed by erosions in the head of the femur, progressive limitation of motion, and increasing pain which are manifestations of inadequate blood supply to that region. Another common cause is the "wear and tear of increasing age and repeated trauma."<sup>4</sup> Significantly, this is a specific malady which usually affects only one hip and is, hence, described as monarticular hypertrophic arthritis. It is not closely related to the usual forms of arthritis and the typical manifestations of the condition are well-known.

*Pathology.*—The pathologic changes seen in this condition are the formation of cystic areas in the spongy bone of the head beneath the articular cartilage, with accompanying cartilaginous degeneration of ischemic origin. In the later stages of the disease there is marked deformity of the femoral head and extensive bony overgrowths about the edge of the articular cartilage of the head. While most of the destruction takes place at the point of maximum weight-bearing, other portions of the head may become sclerotic and more dense than normal, with varying combinations of destruction and bony overgrowth.<sup>20, 33, 43</sup>

All of these pathologic changes in the head of the femur and the adjacent articular cartilage are similar to those seen in the conditions known as "aseptic" or "quiet" necrosis. Impairment of circulation through injury to capsular vessels, or thrombosis, or infarction, or occlusive changes due to arteriosclerosis is

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the mechanical cause of destructive effects upon the bone and cartilage of the femoral head.

*Symptoms.*—Most cases of monarticular hypertrophic arthritis of the hip develop in the fourth and fifth decades of life. They are usually divided evenly between the sexes, and one hip only is commonly involved. In our small group



Skin incision

Vastus lateralis m

FIG. 1.—Drawing showing line of the anterior incision over the hip joint which is used to expose the neck of the femur. (From Stuck and Hinchey<sup>12</sup>)

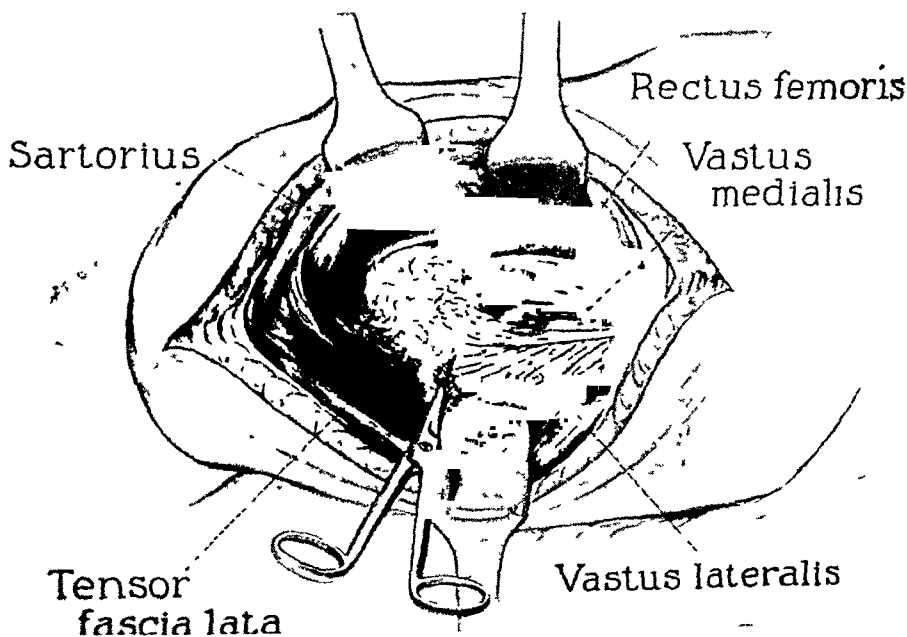


FIG. 2.—Drawing showing exposed anterior capsule of the hip joint and beginning separation of vastus lateralis muscle flap (From Stuck and Hinchey<sup>12</sup>)

of 27 cases, the average age was 35 years, and there were 16 males and 11 females.

The onset of symptoms is slow but progressive, with increasing stiffness and early loss of rotation and abduction. "Catching" sensations may develop

and soon constant pain becomes the most predominating symptom. The pain and associated spasm result in flexion-adduction contractures which produce a disabling limp, or creaking and grating may be noticed when the hip is moved; but it is the constant pain which causes these patients to seek medical advice.

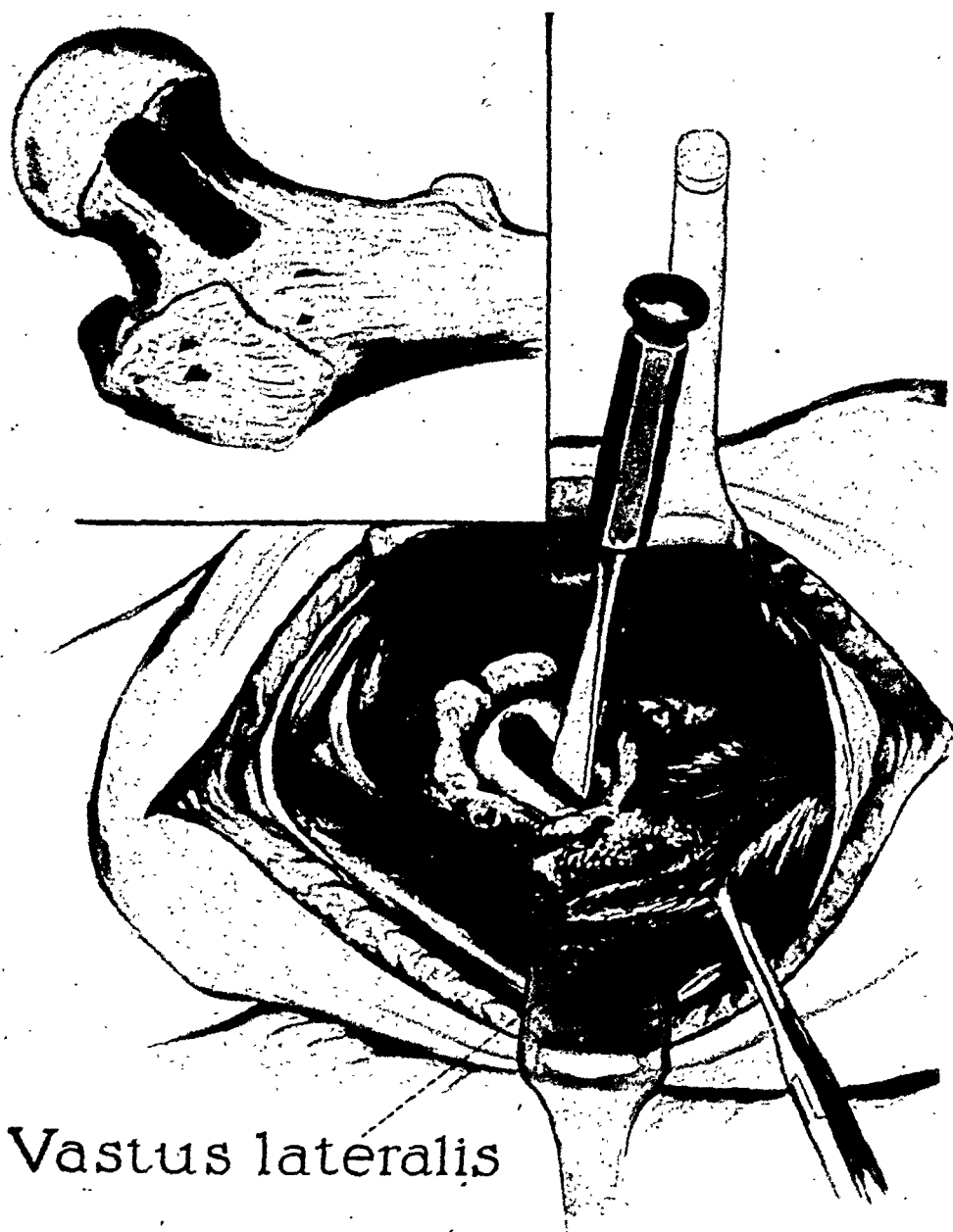


FIG. 3.—Drawing showing incision through the anterior capsule of the hip and formation of groove in femoral neck. Inset shows completed slot in the anterior surface of the neck of the femur. (From Stuck and Hinchey<sup>42</sup>)

Roentgenograms of the hip reveal erosions in the weight-bearing portion of the head, cystic degeneration, narrowing of the joint space and much bony overgrowth about the base which produces the well-known deformed head. In the later stages, there is much flattening of the head and shortening of the neck with partial dislocation of the head and neck out of the acetabulum.

*Treatment.*—Proof that treatment of monarticular osteoarthritis of the hip

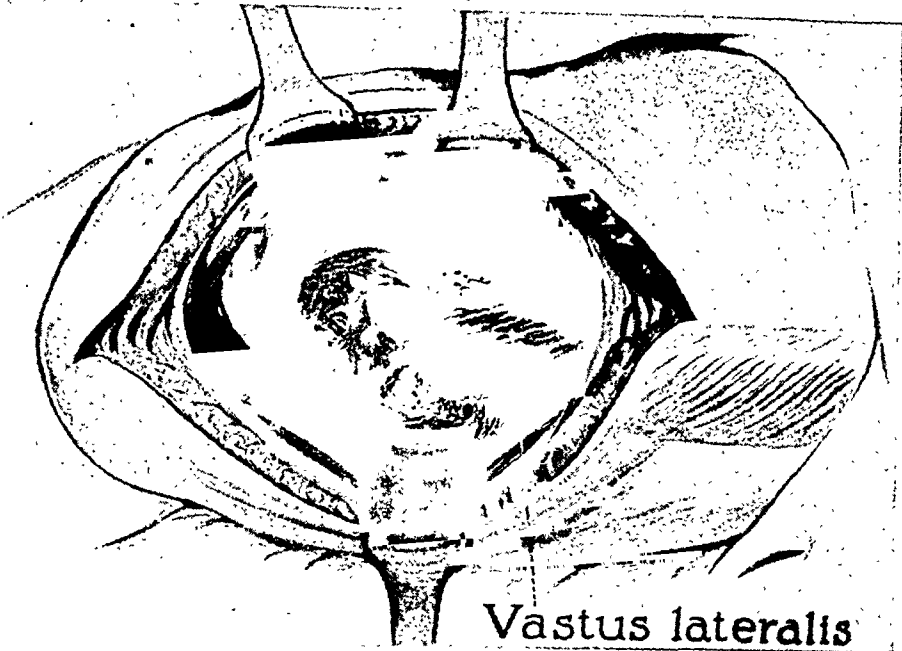


FIG. 4.—Drawing showing completed muscle-flap transplant operation, with a portion of the vastus lateralis muscle sutured into the slot on the anterior surface of the neck of the femur. (From Stuck and Hinchey<sup>42</sup>)

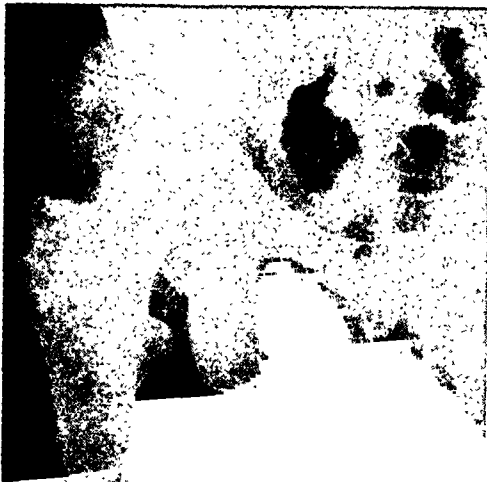


FIG. 5-A



FIG. 5-B

Fig. 5.—(A) F. L. H., male, age 42, had marked limitation of motion in left hip for one year. Had had severe pain for three months. Roentgenograms show destruction of femoral head and "notching" which is occasionally observed.

Fig. 5.—(B) F. L. H. Roentgenogram of hip one month after vitallium cup arthroplasty and muscle-flap transplant operation. Four months later, patient was walking without support and completely free of pain.



FIG. 6-A



FIG. 6-B

FIG. 6.—(A) Mrs. D. W. A., female, age 30, had fractured the right hip three years before, which was treated by well leg traction. Had pain in the right hip and knee more than a year. Roentgenogram shows marked deformity of the head of the femur, with thinning of the joint space.

FIG. 6.—(B) Mrs. D. W. A. Roentgenogram of hip four months after vitallium cup arthroplasty and muscle-flap transplant operation. Ten months after the operation, the patient was still using a cane, and had much voluntary spasm about the hip. We consider this the one case in the series which did not gain satisfactory pain relief.



FIG. 7-A



FIG. 7-B

FIG. 7.—(A) A. C., male, age 22, had had traumatic dislocation of the right hip 2.5 years previously. Had recently developed increasing pain and limp. Roentgenogram shows the typical disintegration of the femoral head in "aseptic necrosis."

FIG. 7.—(B) A. C. Roentgenogram of hip ten months after vitallium cup arthroplasty and muscle-flap transplant operation. One year after the operation, patient walks with no limp, has no pain and is on his feet constantly.



FIG. 8-A



FIG. 8-B

FIG. 8.—(A) W. G., male, age 44, for 18 months had had aching pain in the left hip, with much limitation of motion. Roentgenogram shows destructive osteo-arthritis of the hip, with cystic areas in the femoral head and much thinning of the joint.

FIG. 8.—(B) W. G. Roentgenogram of the hip seven months after muscle-flap transplant operation shows regeneration of bone in the femoral head. The patient was free of pain.



FIG. 9-A



FIG. 9-B

FIG. 9.—(A) J. W., male, age 46. Roentgenogram shows destructive osteo-arthritis of the right hip, with beginning changes in the left hip. Right hip had been painful many months.

FIG. 9.—(B) J. W. Roentgenogram of right hip seven months after muscle-flap transplant operation shows more distinct joint line and more nearly normal bone structure in the femoral head. Pain was relieved.

has not been generally successful is attested by the wide variety of measures which have been suggested and utilized at various times.

Conservative measures such as heat, rest, massage, traction, plaster casts, or crutches provide temporary relief or comparatively lasting benefit in the mild or early stages of the condition.<sup>11</sup> They are of no value in the fully-developed cases however.

Manipulation of the hip under an anesthetic has been advised to correct the flexion-adduction deformity and to alter the point of maximum weight-bearing. Osteotomy of the femur has been performed to achieve the same ends but relief has not been lasting after such a procedure.<sup>16, 17, 28, 30</sup>



FIG. 10.—A. N., male, age 41, had had old slipped femoral epiphysis of the left hip, with normal right hip. Pain on weight-bearing had increased for three years.

Muscle-flap transplant operation performed on left hip 13 months ago. The patient now works as a foreman and is on his feet all day, with no pain.

Sampson-Handley and Sir Robert Jones performed an operation they called "cheilotomy," or trimming of the marginal osteophytes about the base of the femoral head.<sup>17</sup> Magnuson's "joint débridement" is a similar procedure aimed at gaining more motion in the joint by reshaping of the head.<sup>20</sup>

Excision of the head by the Whitman reconstruction or Colonna reconstruction, gives relief of pain but leaves an unstable hip, with considerable shortening. The disability is thereby increased rather than lessened.<sup>15, 16, 18, 46</sup>

L'Episcopo's bone block from the ilium to the neck of the femur is planned for shifting the point of weight-bearing from the head of the femur to the top of the neck. It does not correct the adduction deformity but rather emphasizes it.<sup>23</sup>

Smith-Peterson's "acetabuloplasty" was conceived to increase the range of motion in the hip by the removal of impinging bony overgrowths. The supposition that pain was caused by impingement of the neck against the acetabulum has not been borne out by experience with this operation.<sup>40</sup>



FIG. 11-A



FIG. 11-B

FIG. 11—(A) R. M., male, age 16, had had pain in the right hip two years. Roentgenogram shows slipped femoral epiphysis of the right hip, with normal left hip.

FIG. 11.—(B) R. M. Roentgenogram of right hip three months after muscle-flap transplant operation shows almost complete fusion of the epiphysis of the femoral head. The patient's pain was markedly lessened.



FIG. 12-A



FIG. 12-B

FIG. 12.—(A) C. B., female, age 30, had had old slipped femoral epiphysis, with stiffness of the hip for 15 years and increasing pain for one year. Roentgenogram shows usual mushrooming of the head, with sclerosis at the point of maximum weight-bearing.

FIG. 12.—(B) C. B. Roentgenogram six months after muscle-flap transplant operation shows denser femoral head and neck. The patient's pain was relieved.

Arthroplasty with autogenous fascia gave generally increased range of motion but too often did not relieve pain. There is also a tendency to loss of motion as months elapse.<sup>18, 31, 33, 37, 46, 47</sup>

Arthroplasty with foreign material (steel cups, pyrex glass, viscaloid, bakelite, vitallium, *etc.*) is a simpler operation than the arthroplasty with fascia but, again, the relief of pain is often not sufficient to satisfy the patient. Motion is sometimes permanently increased it is true, but these patients are less concerned with stiffness than they are with pain.<sup>3, 10, 13, 16, 14, 37, 41</sup>

Fusions of the hip by bone graft, Smith-Petersen nail, multiple Smith-Petersen nail, or excision of portions of the head have for the most part given complete relief of pain. However, such operations are not easy, the patients



FIG. 13.—Mrs. C. V., female, age 62, had had fracture of the hip five years before. Fracture was nailed and healed solidly. The patient developed aseptic necrosis and deformity of the femoral head, with much accompanying pain. Removal of the Smith-Petersen nail gave no relief. Muscle-flap transplant operation relieved the pain, and the patient walks with only a slight limp.

are disabled several months and, of course, have a permanently stiff hip.<sup>2, 5, 7, 15, 24, 45</sup>

In other words, no uniformly satisfactory treatment has yet been developed. These patients accept stiffness and limp philosophically, so that arthroplasties to gain motion are measures to correct a secondary complaint. Pain relief is the major goal but has only been gained by excision of the femoral head or some type of arthrodesis of the joint, yet, as pointed out before, these procedures are followed by too much permanent disability.

The most direct methods for relief of pain have been the various drilling operations which have been attempted since David Brainard first suggested the





FIG. 14-A

FIG. 14-B

FIG. 14-C

FIG. 14.—(A) Mrs. J. W., female, age 65, had had a fracture of the neck of the femur which was treated elsewhere by the use of two long vitalium screws. The patient developed nonunion of fracture and pain.

FIG. 14.—(B) Mrs. J. W. Roentgenogram of the hip one month after muscle-flap transplant operation.

FIG. 14.—(C) Mrs. J. W. Roentgenogram of the hip five months after muscle-flap transplant operation showing apparent solid bony union of the fracture. The patient was able to bear her weight without pain.

idea 90 years ago.<sup>6</sup> It is presumed that drilling the head and neck relieves "congestion" or facilitates the passage of capillaries into the neck of the femur.<sup>12, 25, 26, 27, 30</sup> Many patients gain immediate relief from drilling the femoral neck, but the operation has been criticized because the relief is temporary. "Decompression" of the neck is of value, but openings in the bone usually refill with bone in a short time and the pain returns.

#### MUSCLE-FLAP TRANSPLANT

In 1943, Stuck and Hinchey<sup>42</sup> performed a series of animal experiments on the blood supply to the hip and developed a method of increasing the blood supply by a muscle-flap transplant. They followed a lead from Carl Beck's experiments, in which a pedicle-flap of pectoralis major muscle was transplanted into ischemic areas in the heart wall. In these experiments muscle was transplanted into drill holes through the trochanter or into a large defect over the trochanter, but finally the most effective method was found to be the transplantation of a muscle flap into a longitudinal slot cut on the anterior surface of the neck of the femur. In this latter operation, Stuck and Hinchey were able to demonstrate, by injected specimens and by pathologic sections,\* new blood vessels growing from the muscle flap through the slot in the femoral neck and into the spongy bone of the head of the femur. Since this muscle-flap transplant operation was found to provide auxiliary circulation to the head of the femur, and since painful arthritis of the hip is presumably of ischemic origin, and since drilling operations have been unsatisfactory, Stuck and Hinchey devised a similar operation to be performed upon patients with this condition.<sup>42</sup>

Through a curved anterior incision over the hip, the sartorius and rectus femoris muscles are exposed and retracted medially. Blunt dissection is carried down to the capsule of the hip joint and this is incised longitudinally. A slot, about 1 x 4 centimeters, is cut in the neck of the femur from the base of the head to the trochanteric region. A flap from the medial half of the vastus lateralis muscle is dissected free and transplanted into the slot in the neck of the femur. It is anchored with several sutures through the capsule. The wound is then closed in layers.

After the operation, the patients gain rapid relief of pain from the "decompression" of the neck. However, unlike the drilling operations, this pain relief persists because the muscle flap keeps the opening in the bone from closing and in a short time an auxiliary blood supply is directed into the head.

In the first operations we performed this muscle flap at the time we did a vitallium cup arthroplasty. However, we soon discovered that the patients gained relief of pain and sufficient relaxation of muscle spasm if the muscle flap was performed without doing to vitallium cup arthroplasty. Now we have been doing the muscle-flap transplant alone and have found that the

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\* The pathologist's report stated: "Blood vessels effected a direct connection between the perimysium of the striated muscle and periosteum. There was an intimate union between the muscle implants and adjacent bone."

patients gain adequate improvement in pain and function from this simple surgical procedure. Invariably, the patients have remarked on the relief of the deep gnawing pain which plagued them even in bed. Moreover, postoperative roentgenograms have frequently demonstrated increased proliferation of bone and partial regeneration in the head.

The muscle-flap transplant operation has been performed on 27 patients with osteo-arthritis of the hip secondary to old dislocations, adolescent Perthes' disease and slipped femoral epiphyses, old malunited fractures, and the group classed as monarticular arthritis of unknown origin. Of the 27 patients operated upon, 26 have gained marked pain relief, which has lasted as long as two years since the first operations were performed.

The operation is relatively simple, long hospitalization is unnecessary, and postoperative care consists mainly of early motion and weight-bearing. The patients are satisfied afterward, even though the deformity of the head is unchanged and the limp persists, because their pain is relieved and they can resume normal activity.

#### SUMMARY

Painful osteo-arthritis of the hip is a relatively common chronic condition of middle age which produces much pain and disability.

The destructive arthritis of the femoral head follows old adolescent Perthes' disease, slipped femoral epiphyses, dislocations, fractures, or the normal wear and tear of life. Whatever the remote causes, the pathologic changes in the femoral head are due to alterations in the normal blood supply.

We have developed a muscle-flap transplant operation in the head and neck of the femur to overcome the symptoms of "aseptic necrosis" and painful osteo-arthritis. This operation has been performed upon 27 patients and, in all but one case, there was striking relief of pain which has persisted as long as two years afterward. The operation is relatively simple and is indicated in cases of osteo-arthritis of the hip where pain and disability are severe or progressive.

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DISCUSSION.—DR. CHARLES S. VENABLE, San Antonio, Texas: I first want to make it very clear that this is entirely Dr. Stuck's "baby." I was a bystander, more or less innocent, while his experiments were going on, and became enthusiastic when the pathologist was able to show definite regeneration of bone in the head of the femur. So we came to the period when we put these transplants in with a hip cup, and were not able to see much difference, but the astounding thing was that without the hip cup or any other outside influence, within days there was cessation of pain. I did not mention it to him, and he did not mention it to me—it was a difficult thing to explain and still is, except that perhaps the congestion of the blood supply in the hip is relieved by decompression. I think the only explanation for the pain relief is the decompression. We anticipate the regressive change in the blood supply to the head. We think possibly after the immediate relief, the progressive and continued relief of pain—which may be seen in follow-up in the skiagram which shows the difference in the appearance of the head of the femur—there is more space between the articular surfaces. The most interesting singular cases are not only monarthritic joints, but cases of delayed union of fractures in old people. The slides showed a woman, 68 by the score in the Bible and probably 78 by the score of the Lord. She had regression of bone cells at the fracture site. A muscle transplant was done and in 60 days you could see definite early union and at the end of 90 days she was feeding her chickens, which interests me, too.

I wanted you to know this first hand. I think you are open-minded and will be interested in seeing what happens under these changed conditions, and if Doctor Stuck can develop something to relieve these poor devils who never have been relieved for long by anything I have heard of, it will be well worth while.

DR. G. W. N. EGGERS, Galveston, Texas: I have had the opportunity of hearing Doctor Stuck speak of this before. Doctor Venable said it was excellent, Doctor Stuck said he thought it was good, and I figured probably it was fair and I would try it. Possibly I have the unusual honor of being the first to do this operation under their information, so possibly, like the virgin, I may tell of my first experience!

The approach is the anterior approach to the hip joint with which you are all familiar. The systemic reaction is not too great. I believe that when you do something someone else has proposed and endorsed, you have the reaction that you operate not only with the idea of seeing and performing the technical procedure, but also the feeling that you have to be convinced. That was the attitude with which I approached it, and my feeling is this: The vastus lateralis was sensitive in this area and was easy to influence in regression from the neck of the femur. The second point is that the muscle in this area has very few strong fascial bands by which you might anchor it. Third, I wanted to see what the natural blood response would be, so I made drill holes and worked toward the head. You can see the variation in blood response as you make the holes. The bone is quite thin here in the anterior portion of the neck. The only thing I found that helped me was that I was able to anchor the vastus lateralis much more securely to the rectus femoris, and then allow it to drop into the neck of the femur with no tension. To prevent tension I suggested the use of leg traction or a splint to prevent knee flexion. The large lateral cutaneous nerve of the thigh must not be damaged.

That was my experience with it, and I believe it has possibilities. I certainly hope it will open a greater advance than we anticipated and think it may push into oblivion

the vitallium cup or other devices used in this region for arthroplasty of the hip joint, which I do not think are satisfactory for the relief of pain.

DR. RALPH G. CAROTHERS, Cincinnati, Ohio: Those of us who have had the opportunity to pin hips over a number of years have been struck with the type of case, one of which Doctor Stuck showed. Many of us feel if we could anticipate the dead head from the beginning we might remove the head primarily or do an osteotomy. I wonder if and when we can determine which of our cases is going bad, Doctor Stuck's operation might be done as a primary procedure when the hip fracture is seen first. I do not know, but it is a thought.

DR. J. ALBERT KEY, St. Louis, Mo.: I cannot see any rhyme or reason to this operation. The disease is just as much in the acetabulum as in the head of the femur. I am not at all sure that avascularity has anything to do with the pain. I have tried all the operations he mentioned and have also added obturator neurectomy, and the one I like best is the Smith-Petersen acetabuloplasty, plus the neurectomy.

I feel very much discouraged about these hips and have come to the point where my most useful therapeutic measure is a crutch or cane. The immediate relief of pain following the operation must be due to nerve section. I have used drilling without relief of pain. I have done arthroplasties and many are unstable or painful. I am going to try this operation because I have faith in the authors and in spite of the fact that I have not the faintest idea why it should be beneficial.

DR. WILLIAM DARRACH, New York, N. Y.: Albert Key has brought this up, but it was Clay Murray who thought of swinging the muscle in at the time of operation on the neck of the femur, because we had so many cases with insufficient blood supply. We tried it on 21 cases and could not see that there was any difference in the percentage of poor and necrotic heads, and stopped doing it. I think the suggestion of stripping away of the dense fibrous mass in the capsular region is good. We found that if you take a muscle and turn it around and put it in the slot while the patient is under anesthesia, it is best to use precautions so that when he regains consciousness he will not just yank the muscle out of the slot; we have known that to happen.

DR. WALTER STUCK, San Antonio, Texas (closing): Doctor Venable says this is not his "baby." At least he was in the room when the initial conception took place!

Doctor Eggers has found, as we have, that the flap of vastus lateralis muscle must be freed for five or six inches to prevent undue tension. We have been anchoring the flap to the hip capsule with wire sutures.

Doctor Carothers' interest in performing this operation at the time of nailing of a hip fracture is related to Dr. Clay Murray's work. He tried some such procedure but used a very small hole at the fracture line and it was not successful. Moreover, it necessitated too much surgery.

Doctor Key can see no reason for the striking relief of pain after this operation. Neither can we, except that the eventual increased circulation may account for it. The point is that the patients are comfortable and content, and that is their sole concern. They are not interested in roentgenograms or pathologic findings. All they are seeking is relief from constant progressive pain.

# FIXATION OF TENDONS, LIGAMENTS AND BONE BY BUNNELL'S PULL-OUT WIRE SUTURE\*

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OTHER THINGS BEING EQUAL the incidence of postoperative complications will vary directly with the amount and irritating qualities of foreign material which is left in the wound. This is true both of infection and of adhesions, and is especially true of such operations as the repair of tendons, where success depends upon free movement of the sutured structure in the surrounding tissues. It is also true of areas in which the adjacent tissues are subjected to movement or to pressure. Consequently, sutures in tendons, muscle insertions and in areas adjacent to joints should be as simple and nonirritating as possible. Complicated sutures not only implant an excess of foreign material into the wound, but increase the amount of tissue necrosis caused by the suture. In the repair of tendons fine silk has been found to be superior to catgut because it is less bulky, less irritating to the tissues and less apt to be followed by infection.<sup>1</sup>

Fine stainless steel wire (No. 34) was introduced by Babcock<sup>2</sup> as suture material in 1934, and was used by Bunnell<sup>3</sup> for tendon sutures about four years later. It is relatively strong and causes a minimal reaction in the tissues. Bunnell found that the wire might fragment in areas where there had been continual movement over many months, but that this apparently did no harm. Occasionally he noted signs of mechanical irritation from the wire in areas subjected to movement. Consequently, he devised a pull-out wire suture which immobilized the ends of the repaired tendon and held them in apposition until healing occurred and then the wire could be removed, leaving no foreign material in the wound or only a minute coapting suture of fine silk.

In his book on "Surgery of the Hand" Bunnell<sup>4</sup> describes his method of fixing tendons of the fingers to bone and mentions the use of pull-out sutures of heavier wire (No. 30) in the repair of larger tendons, such as the biceps and achillis tendons. It is evident that this method has certain advantages, but it has not come into general use and it occurred to me that experience with the method by another surgeon might be of interest. I have used the method in the repair of tendons of the hand, in fractures of the patella, in the repair of ligaments and especially in the fixation of tendons to bone in tendon transplants.

In the repair of tendons the pull-out suture owes its efficiency to the fact that only the proximal end of the severed tendon tends to retract while the

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## FIXATION BY PULL-OUT WIRE SUTURE

distal end remains relatively immobile if the parts are immobilized. It is applied as follows: Each end of a piece of the fine stainless steel wire (No. 34 for fingers) about a foot long is threaded on a fine needle and bent back and twisted on itself. One needle with the wire is passed directly through the proximal fragment of the tendon about one-half of an inch or more from the cut end and with the needle slanting diagonally distalward, is woven back and forth through the tendon three or four times, care being taken to prevent kinking of the wire as each stitch is pulled taut. Kinking can be prevented by having an assistant guide or if necessary untwist the wire with a pair of smooth thumb



FIG. 1.—Pull-out wire fixation of tendon graft for repair of deep flexor tendon of the little finger (left) and of the middle finger (right).

forceps as the loop is pulled down against the tendon. The other end of the wire is likewise woven through the distal portion of the tendon, but before pulling the first loop taut a pull-out wire suture is placed under the loop.

This pull-out wire suture is a piece of No. 34 stainless steel wire about a foot long which is bent sharply in its middle portion. After it is placed beneath the loop its ends are caught with a light hemostat.

When the two ends of the wire which have been woven through the tendon have been pulled taut the short remaining end of the tendon is cut off and further traction on the wires causes them to sink into the substance of the tendon end. They are then passed down the center of the distal fragment of the tendon or graft for an inch or more and the fine needles are removed and both ends of the anchoring suture are threaded on a larger needle.

The proximal portion of the tendon is then pulled down into position and the larger needle is pushed through the skin distal to this point and removed from the wires which are then passed through a button and pulled taut to fix the end of the tendon in the desired position and tied over the button.



The distal portion of the tendon is then pushed down the wire against the proximal portion and fixed with a single coapting suture of fine silk. The ends of the pull-out suture are then threaded on a needle and brought out through the skin proximal to the tendon suture and left slack. The wound is closed and the part immobilized in a plaster of paris splint or encasement in a position which relaxes the sutured tendon.

Three weeks later, when union of the tendon ends is sufficiently firm, the anchoring wire is cut under the button and traction on the pull-out wire removes it from the tissues. Bunnell states that if difficulty is encountered in pulling it out the end of the pull-out wire should be fastened to a light rubber



FIG. 2.—Double pull-out wire fixation of the patella used in repairing an old rupture of the patella ligament.

band which is then fixed under tension to the skin proximal to the wound and that the wire will be out within 24 hours. In my experience this has not been necessary as all of the wires were pulled out without difficulty, nor have there been any infections in any of the wounds.

In fixing tendons to bone Bunnell scrapes the bone or lifts up a thin flap of bone, perforates the bone with a dental drill and passes the anchoring wires through the hole in the bone and out through the skin and the tendon end is then snugged down against the bone and the wires are tied over a button. Three weeks later the anchoring wire is cut under the button and removed by means of the pull-out wire.

It is difficult to state whether or not the pull-out wire suture is better for uniting tendons in the hand than the suturing with fine silk, which we have used in the past. In my hands, the wire is a little more difficult to use as it kinks very easily and this must be guarded against constantly, and the fine wire is hard to see in the wound. Likewise, the wire tends to cause splitting of a small

tendon graft, such as one from the palmaris longus, more frequently than does fine silk. On the other hand, in no instances has the wire broken as sometimes happens at a critical point when uniting tendons with fine silk.

Undoubtedly the removal of the suture after union of the tendon has progressed to a point where this can be done with safety, is the chief advantage of the method. But when fine silk is used properly this advantage is minimized and it is probable that in the hands of an expert the functional results will be about the same. In the hands of the average surgeon who does only an occasional delicate tendon repair the results should be better where the pull-out wire suture is used. This in spite of the fact that the surgeon may find the operation a little more difficult, and this is my situation.



FIG. 3—Double pull-out wire fixation of the patella in Thompson's method of suturing the ligament or tendon to the major fragment after a fracture of this bone.

In fixing tendons to bones and especially to small bones the method appeals to me as being superior to and less technically difficult than any method which I have used in the past. In tendon transplants in the foot it is especially useful and may even be time-saving. Here a hole large enough to accommodate the tendon is drilled through the bone and the anchoring wire is threaded on a long straight needle and passed through the hole in the bone and out through the skin on the opposite side of the foot. Then the tendon is pulled down into the hole in the bone and the ends of the wire are tied over a button or bar of suitable size.

After the anchoring wire is tied over the button the part must be held in a

position in which the transplanted tendon is relaxed until the wound is closed and the part is immobilized in a suitable splint or a plaster of paris encasement. This efficient external splinting seems to me to be even more important with the pull-out suture than with buried silk sutures which remain *in situ*. In one of my cases in which the extensor tendon of the fifth toe was transplanted to the neck of the fifth metatarsal a plaster encasement was not considered necessary, the anchoring wire was found broken when it was removed four weeks



FIG. 4—Pull-out wire fixation of the transplanted anterior tibial tendon to a tunnel in the cuboid.

later. Fortunately, the tendon had not retracted enough to lose contact with the bone.

It is this necessity for prolonged external fixation which is an objectionable feature in the use of this method for the repair of larger tendons, such as the quadriceps or achillis tendon. When the anchoring wire suture is removed nothing is left except the weak coapting silk sutures. Consequently, external fixation must be continued until the parts are quite safely healed.

Figure 3 illustrates the repair of a fracture of the patella by Thompson's method of excising the distal fragments and suturing the proximal fragment to the patella ligament. In this case the patella was held down by the two

anchoring sutures of No. 30 stainless steel wire which emerged below the tibial tubercle and were tied over wooden cross bars. The postoperative course was uneventful, but it was not considered safe to remove the encasement and the wires until five weeks after the operation. The same was true of the case illustrated in Figure 2, which was an old neglected rupture of the patella ligament which was repaired in much the same manner except that anchoring sutures were placed in the ligament as well as in the bone, thus pulling them together.

•During the past three years I have operated upon two cases in which the heavy silk sutures caused trouble. One was a heel cord which had been severed



FIG. 5.—Pull-out wire fixation of the distally transplanted osseous attachment of the internal lateral ligament of the knee in Mauck's operation for the repair of this ligament. The fragment has tipped up, but not become completely displaced.

close to its attachment to the os calcis and had retracted about three inches. As the wound had occurred over two months before the operative repair the proximal end of the tendon could not be pulled down and it was necessary to split the achillis tendon and turn one-half of it down and suture this to the bone. Some months later a stitch abscess developed and some of the silk was removed. The other was a fractured patella with severe contusion of the soft tissues. This was repaired by Thompson's method and no encasement was applied. A large hematoma developed and drained about two weeks after the operation and eventually it was necessary to open the wound and remove all of the sutures. The infection was minimized with penicillin and immobilization

and the wound healed and later the scar was excised and the patella ligament was resutured to the remains of the patella and a satisfactory knee was obtained. In each of these cases the use of the pull-out wire suture with fine coapting sutures and prolonged immobilization would probably have averted the subsequent trouble.

The pull-out wire suture is useful and suitable for the fixing of ligaments to raw bone, but is not quite so suitable for the fixing of bone to bone because here rigid immobilization is desirable if the bones are to unite. Figure 5 illustrates an instance in which the internal lateral ligament of the knee was tightened by Mauck's procedure of transplanting its insertion downward on the tibia. The semitendinosus tendon was then sutured to the ligament in order to increase its strength. The No. 30 wire was pulled so tightly that the patient complained of pain under the encasement from the pressure of the wooden bar. In spite of this it is seen that the slab of bone which includes the attachment of the ligament has tipped upward a little. Fortunately, the displacement was not enough to interfere with union. But in the fixation of two fragments of bone which are expected to unite by bone such as the patella or the olecranon even a little separation may lead to delayed union or to nonunion.

#### CONCLUSIONS

1. Bunnell's pull-out wire suture is a valuable addition to surgical technic and has a fairly wide field of usefulness.
2. The coapting suture of fine silk and effective postoperative splinting are important parts of the method.
3. The method is not recommended for fixing bone to bone, but is especially valuable in fixing tendons and ligaments to bone.

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DISCUSSION.—CAPTAIN DARREL SHAW, Martinsburg, W. Va.: Doctor Key has mentioned the advantages of stainless steel wire. We have had occasion to use it a great many times, and find it is most useful in repairing flexor tendons of the hand. We have used one of Dr. Bunnell's methods which we believe is quite useful and has certain advantages, that is, using pull-out sutures away from the line of suture or away from the tendon graft. By placing the suture at the wrist to relieve tension the tendon graft may be accurately approximated with very fine silk sutures. There is frequently difficulty in accurately approximating the tendon ends with a stainless steel pull-out wire.

Another little trick is the use of a pin-vise with a small twist drill to drill the small bones of the hand. It is simple to use and readily available. We use a fine crochet hook to pick up the wire. We have found this technic valuable in wiring bones around the face.

DR. CHARLES S. VENABLE, San Antonio, Texas: I cannot for the life of me see why my friend Albert takes so much trouble to make an easy job hard!

DR. J. ALBERT KEY, St. Louis, Mo. (closing): I can only answer Doctor Venable by saying that sometimes it is worth while doing things the hard way.

# MUSCLE FLAP CLOSURE OF CAVITY RESULTING FROM LUNG ABSCESS\*

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THE TREATMENT of lung abscess by external drainage is usually followed by a residual pleuropulmonary cavity with which there commonly is associated a bronchial fistula. The bronchial fistula may be large enough to interfere with respiration and phonation, or it may be so small as to be demonstrated only with difficulty and yet repeatedly infect the cavity, an important factor in its persistence. The natural tendency of the opening in the chest wall to close leads to pocketing with extension of the infection and the development of various complications. In the case of the smaller cavities adequate drainage and limited unroofing may lead to a satisfactory result in the nature of a depression in the chest wall with a bronchocutaneous fistula which may close spontaneously or if it persists can be closed by a pedicled muscle flap. For the larger cavities, with which this paper is particularly concerned, more radical measures are necessary. Collapse by extrapleural thoracoplasty reduces the size of the cavity but fails to obliterate it due to the bronchial fistula, the thickened parietal pleura, and anatomic considerations in the regions of the apex and the scapula. Extensive unroofing deprives the chest wall of firm support so important for proper function, necessitates the severing of a number of intercostal nerves resulting in weakness or herniation of the abdominal wall, and often fails to close the bronchial fistula. A combination of the two avoids unnecessarily radical collapse and undue severance of intercostal nerves. It effectively reduces the size of the cavity but often fails to produce its complete obliteration and a closure of the bronchial fistula.

Such residual cavities can be obliterated by the use of a pedicled muscle flap which serves as an excellent fill, and also has the property of closing bronchial fistulae. Its success is dependent upon proper preparation of the cavity, and its application is limited by the size of flap which can be mobilized in the vicinity. Accordingly, in the case of large cavities it is necessary to prepare them first by providing adequate drainage which must be maintained until closure and then by reducing their size, eliminating pocketing, and making their depths accessible for a muscle transplant. This is accomplished by a combination of unroofing and thoracoplastic measures. Treatment should be directed toward this end from the beginning.

Muscle flaps have long been used in the closure of thoracic cavities. According to Wangenstein,<sup>1</sup> in 1900, Abrasanhoff had sutured a pedicled muscle flap over bronchial stomas, and, in 1911, he implanted the muscle

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directly into the bronchial opening. In 1929, Pool and Garlock<sup>2</sup> demonstrated experimentally that the presenting surface of the muscle becomes covered with bronchial epithelium. In a recent article Carter<sup>3</sup> described the use of pedicled muscle flaps in the obliteration of large empyema cavities, in some cases complicated by bronchial fistulae. He stated that the same principles apply to the cure of chronic lung abscess. Weinstein<sup>4</sup> reported in detail the use of pedicled muscle flaps in filling large defects following the Schede operation for secondarily infected tuberculous empyema. He stressed the fact that for a successful implant the cavity must be clean, and free of pocketing and bronchial fistulae. In 1935, Wangenstein<sup>1</sup> thoroughly reviewed the subject of pedicled muscle flaps in the closure of bronchopleural fistulae. Among other things, he concluded that the cavity should be obliterated at the time of closing the bronchial fistulae, that where possible it is preferable to implant the muscle into the bronchial opening rather than only suture the muscle over it, and that undue sacrifice of intercostal nerves must be avoided so as to prevent the formation of an abdominal hernia. He also observed that decortication often resulted in extensive bleeding and shock. Further historical data are given in the articles mentioned.

Once it has been decided to treat a lung abscess by external drainage, preliminary drainage should be instituted by resecting a segment of rib at the site where the abscess nearest approaches the chest wall and inserting a large mushroom catheter into the abscess cavity at the time, or some days later should the parietal and visceral pleurae not be adherent. Several weeks later adequate drainage is established by inserting a finger as a guide into the abscess cavity and resecting about four inches of two or three ribs over the dependent portion, suturing the skin to the parietal pleura. This necessitates the severing of one or two intercostal bundles, and dividing some thinned-out lung tissue. With drainage, as thus provided, the infection subsides, the patient loses his toxicity, and sputum and cough are reduced to a minimum. The size of the cavity decreases, its walls become smooth, and pockets can be recognized and opened into the main cavity. Further preparation which is directed mainly toward reduction in the size of the cavity is carried out in stages. This is accomplished in great part by the subperiosteal resection of ribs through incisions extending from the thoracotomy wound, or through separate incisions, and limited extrapleural paravertebral thoracoplasty. Unroofing is performed to the extent necessary to maintain adequate drainage, for the recognition of pockets, and for making the depths of the cavity accessible for receiving the muscle implant. The thickened parietal pleura should be excised as it interferes with collapse of the cavity and it often harbors infection which may give trouble later. Due to the fact that a greater portion of the cavity wall is formed by lung tissue there is not the extensive thickening of the parietal pleura commonly present in chronic empyema. The preparation of the cavity for the muscle implant must be carried out in stages as it is impossible to predict the amount and site of lung expansion which will occur, and, accordingly, one cannot judge the degree and the location of unroofing and rib resection which



will be necessary. This has the advantage of conserving the general health of the patient, who, in many cases, works between the stages.

The implantation of the pedicled muscle flap should be undertaken as one stage. The pectoralis major has been found most satisfactory for the upper lobe cavities and the latissimus dorsi for those of the lower lobe. The sacrospinalis muscle is particularly accessible where paravertebral thoracoplasty has been employed, however its segmental blood supply limits the length of flap which can be formed. In an incision extending from the thoracotomy the muscle is widely exposed. In the case of the latissimus dorsi or pectoralis major a large flap is mobilized and severed from its attachment to the humerus. It is thought preferable to leave the base of the pedicle attached to the trunk as this obviates a pull upon the flap with movement of the arm. On the other hand, should it be desired to leave the pedicle attachment uppermost, it still could be detached from the humerus without interference with its blood supply. The

TABLE I  
SUMMARY OF CASES

	No. of Cases
Muscle flap closure—five operations.....	4
Healing with depression in chest wall.....	3
One case about ready for muscle flap closure.....	1
One case—recent unroofing for drainage.....	1
	—
	9

muscle flap must be well mobilized, have a good blood supply, and be free of excess fat and fascia. The cavity is prepared by freeing the skin attached to the external margin and removal of the lining which is accomplished by sharp and dull dissection. This is particularly important in the proximal portion where epithelium has grown inward from the skin. While possibly not necessary in the depths where the lining is thin and pliable, it would appear to favor the adherence of the muscle. In such stripping one may encounter moderate bleeding and may open pulmonary alveoli. The cavity is then filled firmly with muscle which is held with sutures of fine catgut. The bronchial openings are generally too inaccessible or too numerous to permit of directly plugging them with muscle. The skin is closed over the muscle with provision for subcutaneous drainage. A firm dressing is applied and left undisturbed for seven to ten days. There occurs some serous drainage and at times subcutaneous emphyema. The convalescence is generally smooth and the wounds heal nicely. The bronchial fistulae are closed, the muscle gives satisfactory support to the underlying lung and cough is reduced to a minimum. The wound is supported with a chest belt for a period of weeks.

This presentation is based upon a series of nine consecutive cases of lung abscess treated by external drainage. In five of these cases, two of which are reported herewith, external drainage had been instituted prior to their coming under the care of the writer. There were no deaths in this series. A death occurred in an additional patient operated upon for lung abscess in whom the

## LUNG ABSCESS

presence of tuberculosis was not discovered until after drainage had been instituted.

Two illustrative cases are reported. In one a large cavity resulted from gangrene of apparently the whole upper left lobe. In the other there was a large cavity, mostly under the scapula, resulting from a large abscess of the left lower lobe.

### CASE REPORTS

Case 1.—P. D. F. (No. 4895), white, male, age 40, was admitted to the Roper Hospital May 27, 1941. The earlier records are missing and some of the data presented was obtained from abstracts in later records. He had had 12 teeth extracted, and became ill April 13, 1941. Shortly thereafter he developed a cough productive of abundant foul sputum. He had been febrile and had lost weight. On May 17 he had coughed up some



FIG. 1.—Case 1.—December 14, 1943: Cavity just before closure.

blood, and on May 24 he had a severe hemoptysis. Roentgenologic examination showed a large lung abscess in the left upper thorax. This was drained by thoracotomy, with resection of a segment of rib. The process was so extensive that it was termed gangrene of the left upper lobe. The drainage proved to be inadequate and after a few days the thoracotomy was enlarged, with opening of pockets into the main cavity. His condition was critical for weeks. Following a hospital stay of 116 days he was discharged September 20, 1941, with his general condition greatly improved, a large upper lobe cavity, and a bronchial fistula so large that it interfered with phonation and respiration unless a firm dressing was applied. His improvement continued and he attempted work. After a few months his symptoms recurred and he was readmitted in December, 1941, with a severe

cough productive of foul sputum. The thoracotomy opening was enlarged and he was discharged March 12, 1942, greatly improved, but with a large cavity and bronchial fistula still present. Three days later he was readmitted on account of a severe hemorrhage from the chest wound. On this admission a thoracoplasty was performed consisting of the subperiosteal resection of segments of the second, third and fourth ribs posteriorly. Following this his general condition improved and the cavity became much smaller. At this time he came under the care of the writer. The problem was one of maintaining adequate drainage and reducing the size of the cavity in preparation for closure. On January 16, 1943, the first thoracoplasty was revised with subperiosteal resection of the posterior two-thirds of the first rib and further resection of the second and third ribs



FIG. 2.—Case 1. September 29, 1945: Roentgenogram showing amount of collapse, and regeneration of ribs, which add support to the chest wall. No evidence of abscess cavity.

posterior to the thoracotomy. On February 26, 1943, further thoracoplasty was performed with subperiosteal resection of the posterior two-thirds of ribs four, five and six and the inferior angle of the scapula. On July 2, 1943, the anterior segments of ribs one and two and three were resected and the cavity was further unroofed. On December 13, 1943, the patient was admitted for closure of the cavity (Fig. 1). His general condition was good. Sputum and cough were reduced to a minimum. The chest wall opening was 4 cm. in diameter and extended to the periphery of the cavity. The cavity being conical in shape gradually diminished in size, its depth being 6 cm.; at the apex were several small bronchial fistulae. Its walls, consisting of lung tissue, were smooth and pliable. On December 16, 1944, under basal avertin and ethylene anesthesia, the skin was mobilized around the thoracotomy and an incision made anteriorly. The lateral half of the pectoralis major muscle was mobilized so as to form a pedicle with its base at its origin on the chest wall, the attachment to the humerus being severed. The lining of the cavity was then removed by sharp and blunt dissection. The peripheral portion stripped off easily; in the deeper portion moderate bleeding was encountered. This was readily controlled with

## LUNG ABSCESS

light gauze packing. The muscle flap was placed firmly in the cavity and held to some extent by several sutures of plain catgut. Skin closure was then effected, with insertion of a subcutaneous drain. A firm dressing was applied. For a few days there was some



FIG. 3.—Case 1. June 20, 1945: Eighteen months after closure of cavity.



FIG. 4.—Case 2. June 25, 1945: Cavity just before closure. Forceps lifting superior margin to show depth.

soft tissue emphysema in the pectoral region. The wound healed readily. The patient was discharged December 26, 1944. He was last examined November 3, 1945—his general condition was excellent. He had no cough or sputum. Clinical and roentgenologic examination (Fig. 2) showed no evidence of abscess cavity. The operative wound (Fig. 3) which was in the axilla and supported by the upper arm, bulged only slightly on straining.



FIG. 5.—Case 2. September 19, 1945: Roentgenogram showing amount of collapse, and regeneration of ribs, which add support to the chest wall. No evidence of abscess cavity.



FIG. 6.—Case 2. September 25, 1945: Three months after closure of the cavity. Small area of lung exposed, later (November 20, 1945) this was covered by muscle flap and skin.

**Case 2.**—H. F. (No. 7845) white, male, age 43, was admitted to the Roper Hospital May 14, 1942. He had been taken ill eight weeks previously with a severe pain over the left lower chest, night sweats, and fever. A cough developed, which gradually became severe and productive of abundant foul sputum. Upon admission his temperature was 101° F.; he was weak and lethargic. He had lost considerable weight and had skin changes indicative of vitamin deficiency. Roentgenologic examination showed a large abscess in the lower left thorax. Sputum examination was positive for Vincent's organisms. He was given neoarsphenamin and sulfonamide therapy. Bronchoscopic drainage was performed May 18, 1942. There being no improvement of note, external drainage was decided upon. On May 26, 1942, the abscess was drained through a thoracotomy, with resection of a segment of the eighth and ninth ribs in the posterior axillary line. The cavity was described as being 8x8x10 cm. in size. He was discharged June 3, 1942, his general condition greatly improved. The thoracotomy showed a marked tendency to close, and in order to maintain adequate drainage it had to be revised by excision of thick fibrous tissue and subperiosteal resection of the ribs in the vicinity on August 28, 1942, November 6, 1942 and February 8, 1944. During this period his general condition improved, permitting him to work in between visits to the hospital.

The cavity decreased in size due to expansion of the lung and depression of the chest wall resulting from the rib resection. Its walls became smooth, the bronchial fistula continued to be large, interfering with respiration and phonation when the dressing was removed. While fibrous thickening took place in the region of the chest wall, the pulmonary walls of the cavity remained pliable. At this stage the cavity was about 5 cm. in diameter and 10 cm. deep. It was situated mostly under the scapula. On May 16, 1944, further collapse was effected by resection of the lower angle of the scapula and subperiosteal resection of the posterolateral segments of two underlying ribs. In final preparation for closure, on January 26, 1945, further unroofing was effected and the posterior segments of the seventh, eighth, and ninth ribs were subperiosteally resected. On June 19, 1945, he was admitted for closure of the cavity (Fig. 4). The diameter was about 5 cm. at the chest wall and gradually diminished toward the apex, which was about 8 cm. deep. The lining was smooth, the walls were pliable, and there was a moderate-sized bronchial fistula at the apex. On June 25, 1945, under continuous spinal anesthesia, through an incision extending anteriorly from the thoracotomy the post two-thirds of the latissimus dorsi were mobilized, and its attachment to the humerus severed. The lining of the cavity was next removed by sharp and blunt dissection. This proceeded well until the distal one-third of the cavity was reached, when coughing and respiratory embarrassment made it advisable to hasten the ending of the operation. The prepared muscle flap was firmly packed into the cavity and held in place by a few catgut sutures at the outer edge. The skin edges were then approximated in an unsatisfactory manner as inferiorly the skin had not been freed from the chest wall. A subcutaneous drain was inserted and a firm dressing applied. Except for a moderate amount of serous drainage, convalescence was uneventful. He was discharged July 12, 1945. On November 18, 1945, his general condition was good, he was free of cough and sputum. Clinical and roentgenologic examination (Fig. 5) showed no evidence of abscess cavity. On coughing there was a moderate degree of bulging in the operative region (Fig. 6). Between the skin edges there was an exposed strip of lung 3 cm. long and 0.5 to 1 cm. wide; there was no escape of air on straining. On November 20, 1945, pedicled muscle flaps of latissimus dorsi and sacrospinalis were placed over the exposed lung and the surrounding bulging area. On December 1, 1945, his temperature was normal and there was every indication of a satisfactory result.

#### SUMMARY

The treatment of lung abscess by external drainage is usually followed by a residual pleuropulmonary cavity, with an associated bronchial fistula. Such a cavity properly prepared by adequate drainage, unroofing and thoracoplastic

measures may be obliterated by implanting a pedicled muscle flap. Two illustrative cases are reported.

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DISCUSSION.—DR. ROLLIN A. DANIEL, JR., Nashville, Tenn.: Dr. Prioleau has emphasized several points which are of importance regarding this method of closure of large pulmonary cavities. First, this method of treatment results in considerable deformity and some fixation of the chest wall. Second, in most cases there are multiple bronchial fistulae. Third, Doctor Prioleau has emphasized the importance of stripping away the lining of the cavity before muscle flaps are placed in it. I would like to call attention to the fact that good results can frequently be obtained by making an incision through an intercostal space or the periosteal bed of an excised rib and performing lobectomy. It may be possible to excise only a part of the lobe in order to get rid of the cavity. This can be done, as Doctor Prioleau has pointed out, following preliminary drainage of the abscess, and after the cavity has become clean. One should free the remaining lung tissue or a part of it from the chest wall. After this is done the wound can be closed and the air removed from the pleural cavity, or a tube may be left in the pleural cavity and suction applied so that the remaining lung may expand to completely fill the pleural space and close the cavity. We have done this in several patients and in three cases have found that large cavities which had been present for a long time were lined with pseudostratified epithelium.

## DYSCHONDROPLASIA\*

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THIS PRESENTATION will be limited to a particular group of chondrodystrophies which are usually generalized and familial in character. It is not to be confused with other forms of chondrodystrophy, such as Morquio's disease. ("A rare development disease often familial in character with skeletal abnormalities and resultant dwarfism and generalized body deformity.") (Hirsch<sup>1</sup>)

The cases under consideration have been under observation for periods varying between 15 and 25 years.

My first report was presented to the Southern Surgical at White Sulphur in 1931. ("Skeletal Disturbances and Anomalies"<sup>2</sup>). At that time I reviewed briefly the literature on the subject.

In 1898, Ollier suggested the name dyschondroplasia.

Sir Arthur Keith,<sup>3</sup> in 1919, suggested the term "Diaphyseal Aclasis" because the main incidence of the disturbance falls upon the modelling or pruning of the diaphyses.

As late as 1930 one could still find statements like the following: "The etiology of chondrodysplasia remains a mystery."

In 1928, Murk Jansen<sup>4</sup> advanced a theory with reference to dyschondroplasia. This theory I believe is substantiated and fully explains all of the phenomena noted in connection with observed cases. I believe that it warrants acceptance generally.

Augusta Gaskell<sup>5</sup> states:

"A theory that does not account for all of the facts which are involved is an inadequate solution. In order to be entirely acceptable the theory must be both sufficient and necessary. This means that the theory must fully account for the phenomena under consideration and that they cannot be accounted for on any other hypothesis."

Fisk states:

"A scientific explanation is a hypothesis which admits of verification—it can be either proved or disproved."

Gaskell further remarks:

"A hypothesis or a theory is a thing of merely temporary existence and that proof converts speculation into knowledge, and theory into accepted facts."

I believe that Jansen's theory fulfills the necessary criteria.

It must be admitted that continued investigation into natural phenomena results in the addition of fragments of knowledge which when pieced together produce composite pictures which represent the present evolutionary stage of human knowledge.

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\* Read before the Fifty-seventh Annual Session of the Southern Surgical Association, December 4-6, 1945, Hot Springs, Virginia.



Deformities which we find in the human body are not to be accepted as accidents, but as definite evidence of retardation or dissociation processes.

The development of the human skeleton goes along in an orderly manner in obedience to a well defined plan, unless there is a factor which delays or alters the plan.

This factor may be present in the germ plasm or it may result from chemical influences exercised on the developing embryo. The hereditary factors present in the germ plasm may be dominant or recessive in character following the mendelian law.

Maud Sly, and others, have proven this beyond cavil.

Bagg<sup>6</sup> and Stockard,<sup>7</sup> distinguished embryologists, and Jansen have proven that defects are due to retardation during the embryonic period or to disturbance of the germ plasm which may be evidenced for generations.

In 1914, Potel<sup>8</sup> pointed out that:

"Primitive embryonic cells are endowed with almost indefinite powers of proliferation and they enclose material for several differentiations.

"When a modification of the medium or environment supervenes the plastic cellular substance endeavors to adapt itself to the new vital conditions offered to it. It develops in an atypical manner. Differentiations are diminished, modified, or even arrested. Gradually recovery ensues and the phenomena of differentiation and proliferation are restored. The momentary arrest results in a loss of equilibrium and a local modification manifests itself under the aspect of a malformation."

Such retardation in the germ plasm results in dissociation retardation phenomena which are recognized in the human body and in this instance in the form of total retardation of tubulation, lengthened metaphyses, or partial retardation of tubulation (exostoses).

In 1919, Sir Arthur Keith asserted:

"Multiple exostoses are usually placed by surgeons in the category of tumors, but a close examination of anatomical changes shows that they should be definitely placed among the disorders of growth."

Sir Arthur Keith was able to show that:

"John Hunter had recognized the modelling or pruning process by which the new bone laid down was pruned, reformed, and incorporated as an intrinsic architectural part of the cylindrical shaft."

It remained for Jansen<sup>4</sup> to present the theory which I believe establishes the real nature of the condition under discussion. Jansen postulates:

"Six different processes and probably more have to coöperate harmoniously in order that the bones shall attain their proper size, shape, structure, and composition, when completing their growth. These processes are resorption, tubulation, cancellation, cell division, cell enlargement, and differentiation.

"Sometimes one or more of these processes will be delayed with regard to the other processes during a shorter or longer period, and the dissociation of each of these processes evokes its own characteristic symptom.

"The clinical picture is characterized by its extreme polymorphism. In some cases only a single bone is found to be affected, and, in others the condition presents itself on both sides."

Discussing pathogenesis, Jansen says:

"During growth the epiphysis is displaced distally by the growth disk, the metaphysis is not. It stands to reason that only if tubulation keeps pace with longitudinal growth of bone, will the normal funnel-shape of the diaphysis end close to the epiphysis; whereas an approximately cylindrical area of cancellous tissue produced by the growth disk must be expected to lie between the funnel-shaped end of the metaphysis and the growth cartilage when tubulation is retarded. Hence, the conclusion presents itself that the cylindrical or barrel-shaped area between the growth cartilage and the *funnel-shaped metaphysis is caused by a retardation of tubulation* and exostoses are the result of partial retardation of tubulation. These two phenomena appear to us to be the result of a total and a partial dissociation through retardation of tubulation with regard to the other processes of longitudinal growth."

The personal observations made in this paper are based on a study of cases over a period of 25 years. In one family there is evidence of the condition in three generations, and in another I have observations in two generations. There is suggestive evidence of at least six or eight generations in one instance (Bartel and Bardwell families).

There is so much to be said and the time so limited the presentation must of necessity be brief.

1. Dyschondroplasia is an hereditary retardation phenomenon.
2. Dyschondroplasia affects the shafts of long bones particularly near the ends of the diaphysis.
3. It does not primarily affect the epiphyses. In well-developed cases the epiphyses can be shown to be normal in character, especially is this true of the lower end of the femur, the upper end of the tibia, the head of the humerus, and the lower ends of the tibia and fibula. The deformities noted in epiphyses are secondary changes.
4. One of the terms used in connection with this condition "multiple epiphyseal enchondromata" has no place in the real nomenclature of the condition. In dyschondroplasia the shafts of the metacarpals and phalanges are affected, but not the epiphyses.

5. There is apparently no difference in the transmission to either sex.

6. The condition may be limited to a single bone, particularly the radius giving rise to the condition commonly spoken of as Madelung's deformity. The so-called Madelung's deformity was first described by Madelung at the seventh German Surgical Congress in 1878. Many cases have been presented and suggestions made as to the etiologic factors involved. A remarkable study of this condition was reported by DeWitt Stetten,<sup>11</sup> of New York, in 1909. He stated: "The radial curvature is due not to a disease of the cartilage, but to an irregular ossification involving principally the lower end of the shaft where the growth is most active."

7. Dyschondroplasia may be unilateral. In some instances I have observed a normal humerus on one side and evidence of dyschondroplasia on the other. (Note case of Iona Leich.)

8. Dyschondroplasia is progressive in its manifestations up to complete ossification of the epiphysis and the diaphysis. After full growth has been reached, there is no further evidence of progress of the condition.

9. At birth and during the first few months of life one may not find roentgenographic evidence and at a later period changes characteristic of the condition are found. (Baby Messmer.)

10. When there is a unilateral manifestation of the condition one finds the characteristic short forearm on one side and a normally developed forearm on the other.

11. True cases of dyschondroplasia manifest evidence of dissociation phenomena which may be both partial and complete.

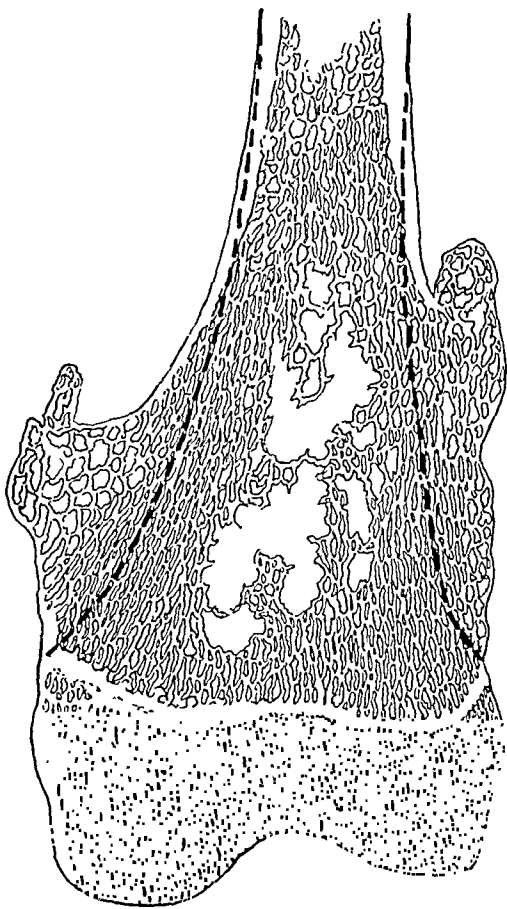


FIG. 1.—Dotted lines indicate normal tubulation. Irregular areas outlined indicate failure of resorption and tubulation. Broad metaphysis can be noted. Clear spaces indicate delay of cancellous.

12. Where partial retardation phenomena alone exists we note exostoses.

13. Where total retardation of tubulation occurs long or wide metaphyses are noted. In some instances in the same bone one does note both total and partial retardation phenomena, evidenced by wide metaphyses and spur-like exostoses (Fig. 1).

14. We have noted involvement of all bones laid down in cartilage but have so far not seen evidence of the condition in bone laid down in membrane such as the skull.

15. It is remarkable to note that in most instances there is little or no disturbance of function of the joints and comparatively little pain complained of by any of the patients I have seen.

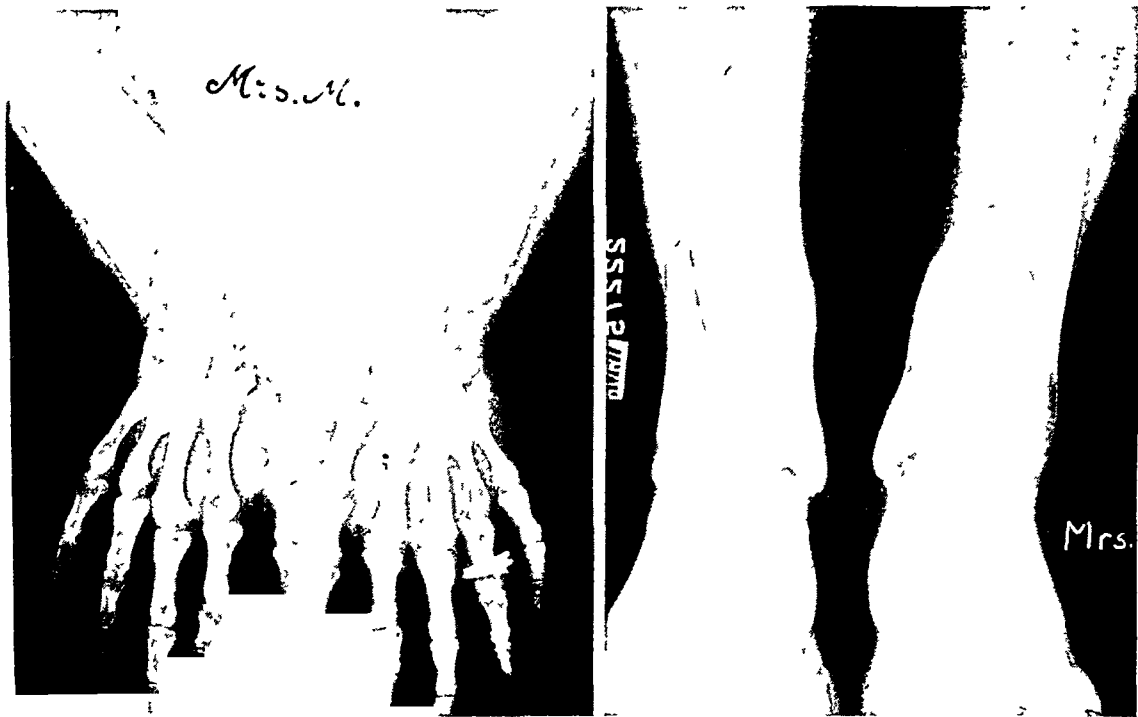
16. The condition should not be considered a disease. It is pathologic in the sense that there is a lack of harmony in the various processes which have to do with normal bone growth.

17. There is no indication to operate unless the individual mass interferes with joint function.

18. It is important to avoid surgery during the early period of growth as operation may favor shortening of the limb by premature ossification at the epiphyseal line.



FIG. 2.—Case 1: J. C., — Dyschondroplasia.



FIGS. 3-4. Case 1: J. C., — Dyschondroplasia.

19. Only pedunculated masses which interfere with motion or function should be removed.

## CLINICAL REPORT

A very brief abstract of examination in each instance is made in this report.

## Case 1.—Jennie Chappetta (Case 7 of original report).

This patient has been followed continuously since 1921. She has had one full term pregnancy. (Delivery was effected by cesarean section because of the marked distortion of the pelvis). She has suffered no inconvenience. There has been no limitation of her activities.

Pictures taken in 1945 indicate that the sites from which some of the larger masses were removed have shown no evidence of recurrence or further progress of the process (Figs. 2, 3 and 4).

Case 2.—Annette Messmer (daughter of Jennie Chappetta) shows the stigma in the right femur, and a node on the eighth rib (Fig. 5).

Note: In an attempt to obtain evidence in previous generations, I have not been able to obtain positive information. The grandfather has no evidence of skeletal deformity.

The mother is one of 11 children and four of these have polycythemia vera, familial type. The grandfather of the baby stated that he had three brothers and two sisters; his father was tall and his mother was "short," but he has never noted in any of the family evidence of deformities of any kind.

## Bardwell Family—

In the family about to be reported six cases in two generations have been personally observed.

From the history there is evidence that several other members of these two generations have the same skeletal character.

## Case 3.—Mrs. Lewis Bardwell Nott, age 45, height 5 ft. 1.5 inches.

The right forearm is shorter than the left. There is loss of the carrying angle; and there is a deformity of the wrist with deviation of the hand to the right.

There is a large bony prominence on the shaft of the right humerus just below the head; a similar though larger mass can be palpated on the left humerus.

There is no limitation of motion of either knee, but on the inner aspect of the right thigh there is a large bony prominence which extends down about three inches and can be



FIG. 5.—Case 2: A. M., (daughter of J. C.)  
—Dyschondroplasia.

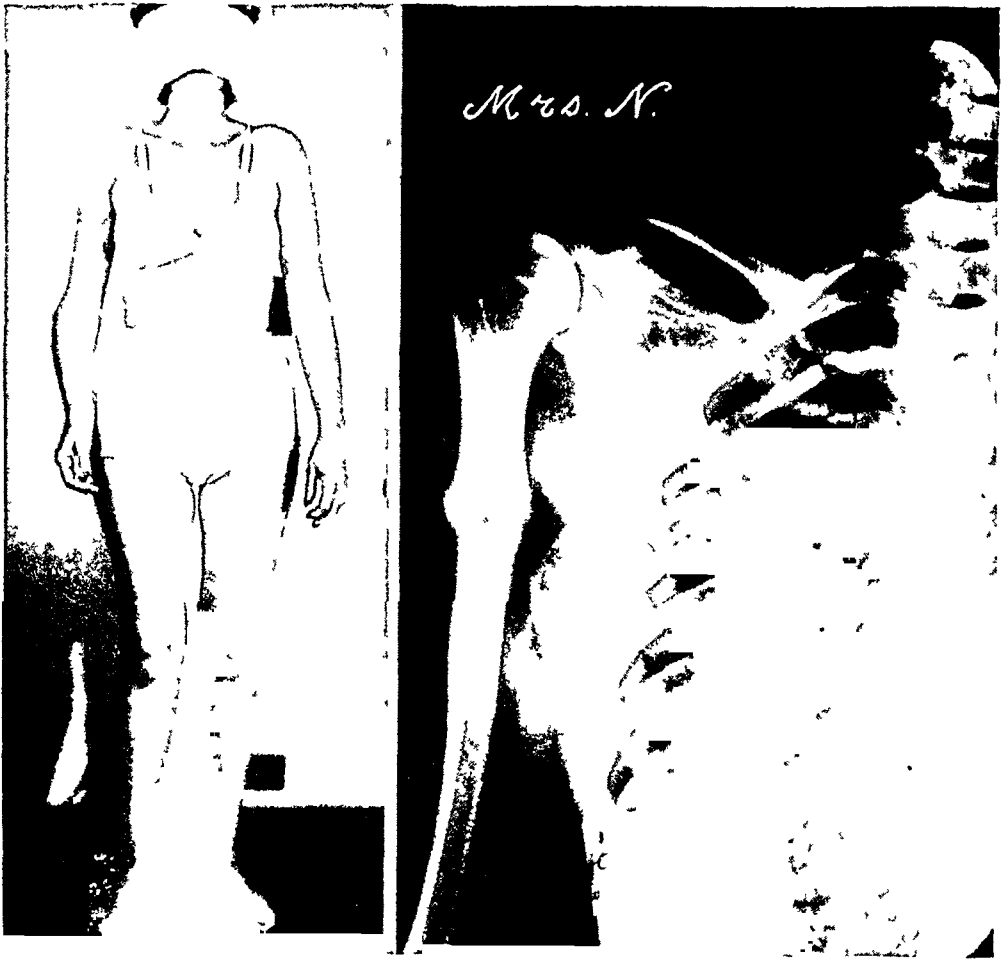


FIG. 6-7.—Case 3: Mrs. L. B. N., — Dyschondroplasia.



FIG. 8-9.—Case 3: Mrs. L. B. N., — Dyschondroplasia.

palpated in the popliteal space. On the left fibula the bony masses are more prominent than those on the right (Figs. 6, 7, 8 and 9).

**Case 4.**—Lewis Nott, age 9, son of Mrs. Bardwell Nott, was examined in 1932, at which time there were skeletal retardation phenomena noted symmetrically on the long bones of the upper and lower extremities.

*Note:* The mother stated that he has not been incapacitated in any manner as a result of the condition.

**Case 5.**—Eugene M. Bardwell, age 26. He is one of 11 children.

Patient states that his condition has never interfered with his activities. Right forearm is shorter than the left. There is a loss of the carrying angle on the right side.

There is no limitation of motion of the joints of the upper extremities.

He has large bony prominences on the ribs, particularly the fourth, fifth, and sixth ribs on the left side.

**Lower Extremities:** There is loss of symmetry of the two legs. There are bony masses palpable on the long bones of both lower extremities.

"Roentgenologic examination, October 30, 1945, (No 23084) of the right shoulder and arm, the right forearm, the right knee, and the left ankle reveals findings characteristic of metaphyseal aclasis (hereditary deforming dyschondroplasia)" (Figs. 10, 11 and 12).

**Case 6.**—Earl Bardwell, age 28 First seen in September, 1932. Patient was next seen on October 23, 1943, when he returned to the office at my request.

This young man was inducted in the Army on April 26, 1945, and discharged for disability July 4, 1945. He stated that: "Most all of the boys in the Bardwell family have the same thing. My mother is normal, all of the Bardwell family are involved."

**Examination.**—October 23, 1945. There is loss of the carrying angle; the forearms are short and there is a marked bowing.

There is loss of symmetry of the shoulder girdles, there is a tilting of the pelvis; on the inner aspect of the knees there are marked bony bosses, particularly on the right side, and on both tibia there are large, nodular, painless bosses. There is no limitation of motion of either ankle.

"Roentgenologic examination, October 22, 1945, (No. 22719) of the right shoulder, forearm, knee, and ankle, and of the left hip reveals multiple manifestations of metaphyseal aclasis (hereditary deforming dyschondroplasia)." (Figs. 13, 14, 15 and 16).

**Case 7.**—Huey Bardwell, age 15 (October 30, 1945).

In spite of the fact that he has dyschondroplasia he is able to play football and has never been handicapped in any way. Height 4 feet 10 inches

**Examination:** Short forearm (right). Both forearms show marked deformity but more marked on the right—there is a radial deviation of the hand. Bosses are seen as well as palpated on the lower end of the radius and ulna. There is no limitation of motion of either wrist or elbow. Bony prominences on the upper end of both humeri



FIG 10.—Case 5: E. M. B.  
—Dyschondroplasia.

Palpable mass over the lower end of the ribs, particularly the right side. Lower extremities are short, bony prominences above and below both knees. There is no limitation of motion of either knee in spite of the fact that the mass on the inner side of left knee is about the size of a small orange. There is no limitation of motion of either ankle, but the bosses are prominent on the lower end of the fibula on the left.

"Roentgenologic examination, October 30, 1945, (No. 23087) of the right forearm and knee and the left leg reveals findings characteristic of metaphyseal aclasis (hereditary deforming dyschondroplasia). Irregular calcareous deposits in the soft-tissue component



FIGS. 11-12.—Case 5: E. M. B., — Dyschondroplasia.

of an osteochondroma arising from the medial surface of the proximal tibial shaft indicates that this part of the tumor is predominantly cartilaginous and interval studies to determine its rate of growth are advised." (Teitlebaum) (Figs. 17, 18, 19 and 20).

Case 8.—Sybil Bardwell, age 10 (October 30, 1945). Diagnosis: Dyschondroplasia.

Examination: Right forearm shorter than the left. Both shoulders are prominent. Bosses noted on the right, particularly below the pectoral groove. Madelung's deformity, with the deviation of the hand to the radial side. There is no limitation of motion of any of the joints of the upper extremities. On the left forearm there are bosses on the radius and the ulna. On the ribs there are large bosses. There are bony masses on the left above the condyles which extend down into the popliteal space. There are large bony prominences on the upper end of the tibia and fibula and along on the tibia and fibula of both legs just above the ankles.

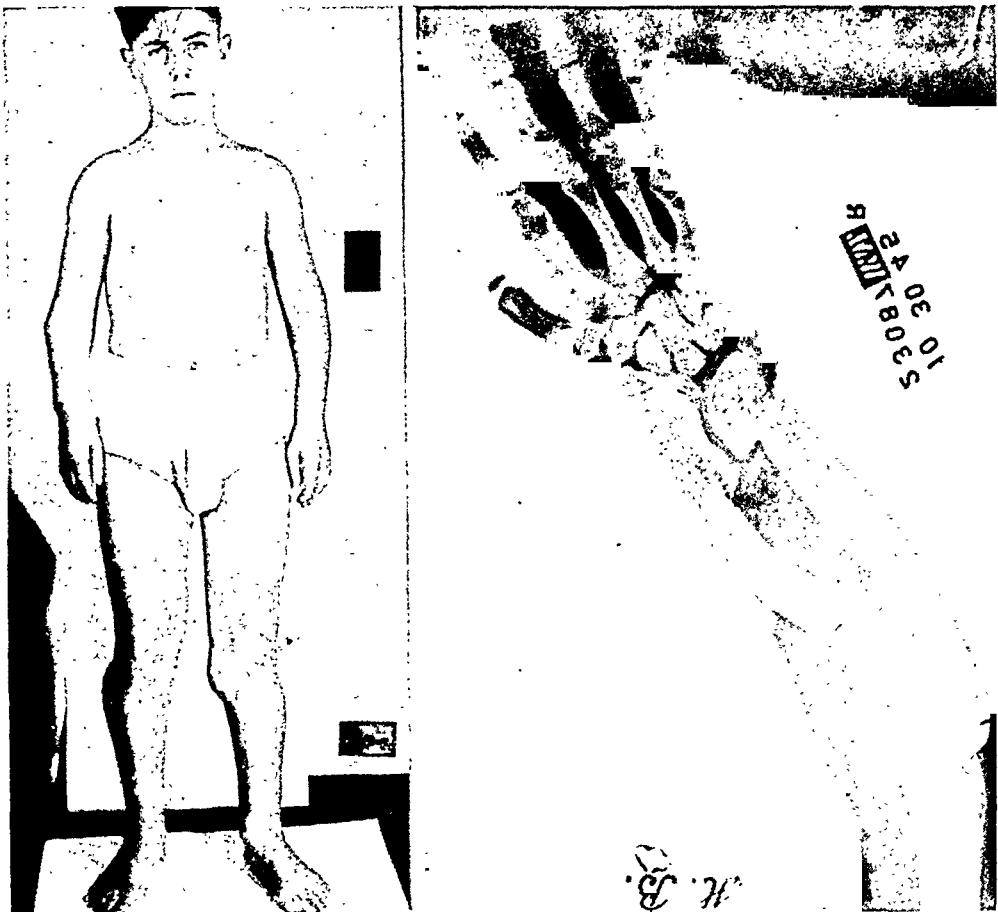




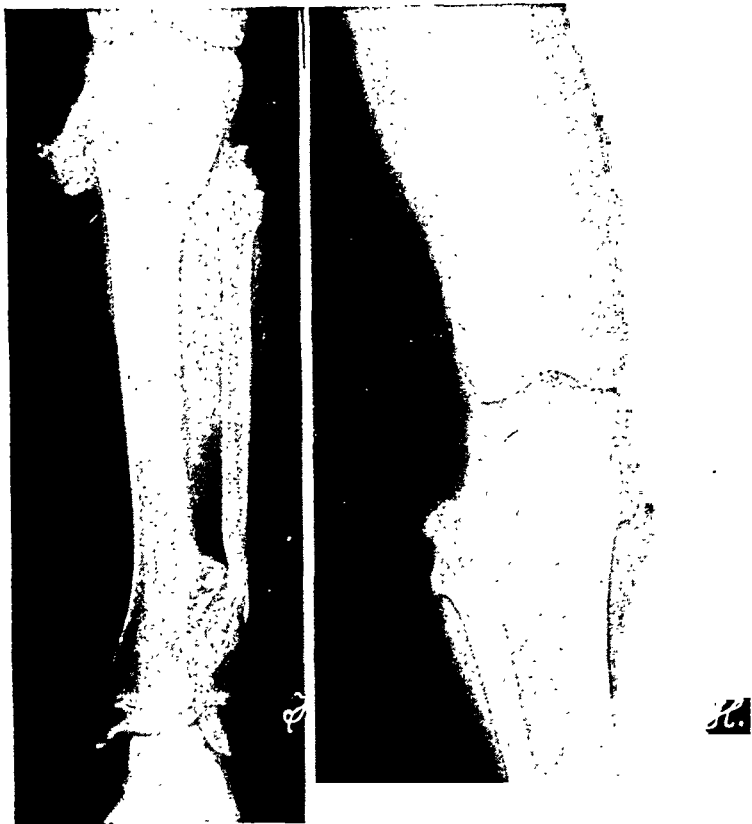
FIG. 13.—Case 6: E. B., — Dyschondroplasia.



FIGS. 14-15-16.—Case 6: E. B., — Dyschondroplasia.



FIGS. 17-18.—Case 7: H. B., — Dyschondroplasia.



FIGS 19-20.—Case 7: H. B., — Dyschondroplasia.

Roentgenologic examination, October 30, 1945, (No 23085) of the right shoulder and arm, the right forearm and the left knee reveal changes typical of metaphyseal aclasis (hereditary deforming dyschondroplasia) (Figs. 21, 22, 23 and 24).

Case 9.—Mrs. E. A. A., age 32, was first seen in 1926, and reported as Case 6 of the original report. This is the only case in the series in which the condition was limited to one bone—the radius.

A follow-up roentgenogram, (No. 23350) November 5, 1945, indicates that there has been no progress of the deformity since complete fusion of the epiphysis and diaphysis. "Examination of the left forearm reveals a deformity characteristic of metaphyseal aclasia (hereditary deforming dyschondroplasia)" (Fig. 25).

Case 10.—Iona Leiche, age 7. September 10, 1932 Patient brought here after mother had been informed that her child had a peculiar bone disease but that nothing could be done

Examination—Child seems to be well-developed Left upper extremity is shorter than right. The forearm is bowed. The deviation being to the ulnar side. The forearm itself is much shorter. All of the fingers of left hand present bosses on at least two phalanges. Lower extremities are apparently same length. Crest of ileum on left side seems larger than right Right shoulder Head of humerus rotates without limitation of motion. No masses palpable over humerus, radius or ulna

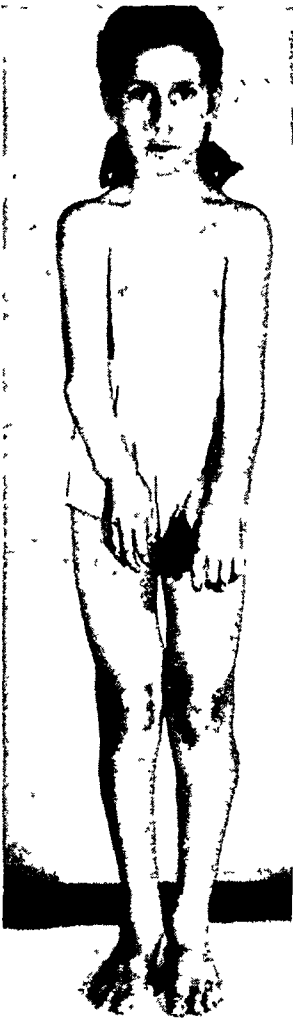


FIG. 21.—Case 8: S. B., Dyschondroplasia.



FIGS 22-23-24.—Case 8: S. B., — Dyschondroplasia.

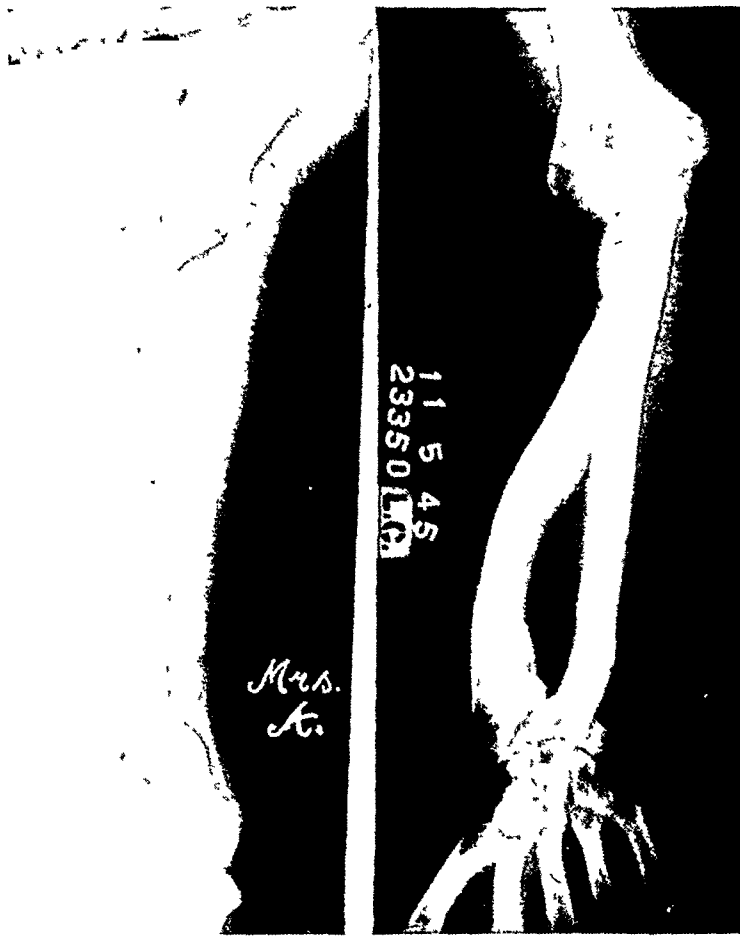
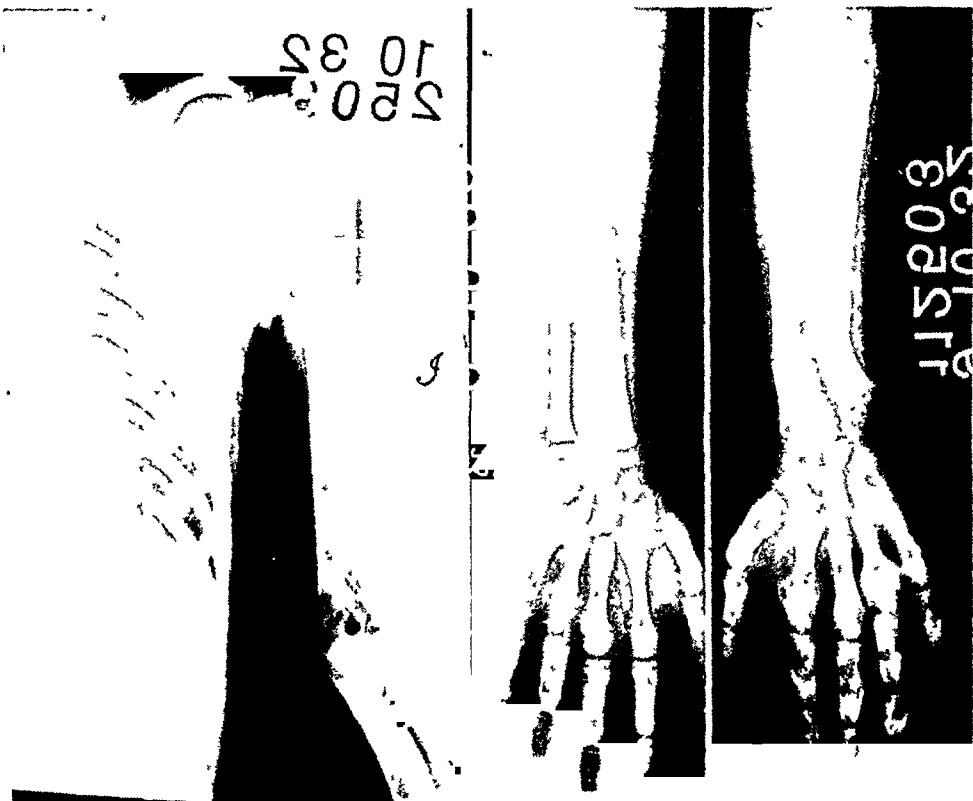


FIG. 25.—Case 9: Mrs. E. A. A., Dyschondroplasia limited to one bone—radius



FIGS. 26-27.—Case 10: I. L., Dyschondroplasia—Asymmetric nature of condition noted in radius and ulna of the two forearms. Marked involvement of metacarpals and phalanges.

**Fifth metacarpal:** This presents large bony mass at its lower end. There seems to be a fusiform enlargement. There are hard bony bosses on the phalanges on all except thumb and index finger.

**Left side:** Head of left humerus larger than right; large bosses palpable on it.

A number of bosses are palpable on lower third of radius and ulna. Ulna is shorter than the radius. Bosses are on phalanges and metacarpals, larger on left than right.

Roentgenologic examination, September 9, 1932, (No. 1112503): "There is observed well-defined dyschondroplasia here which seems decidedly more extensive upon the left side in the upper extremity than in the right upper extremity. Fairly large areas of cartilage can be observed in the phalanges of the little and ring finger of the right hand, as well as the small and proximal phalanx of the middle finger. The metacarpals of the same three fingers on the same hand, likewise show the same type of change. In the arm and forearm, however, upon the right side no such island can be observed. In the left upper extremity the phalanges of all fingers, the metacarpals of all fingers, the radius and the ulna, as well as the upper end of the humerus and the scapula show rather extensive islands of cartilage, and in all cases these appear nearer the epiphyseal line than in the middle portion of the bone." (Figs. 26 and 27).

**COMMENT:** This case illustrates very well the asymmetric nature sometimes noted. The radius and ulna on one side normal in appearance; there is marked involvement of the radius and ulna on the other.

The involvement of the metacarpals and phalanges are probably as well noted in this case as any I have ever seen.

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**DISCUSSION.**—DR. IRVIN ABELL, Louisville, Ky.: Doctor Cohn has kindly consented to my showing some slides of a patient who came to us for an acute appendicitis. He presented such a multitude of skeletal tumors that after his recovery from the operation for appendicitis a study was made. Some of the films are shown today, not so much because of the rarity of the lesion as because of the number and extent of the tumors; 91 being revealed on the roentgenograms. The case conforms to the pattern of hereditary

deforming chondrodysplasia, in that numerous tumors were present, accompanied with skeletal deformities which arose between childhood and maturity and involved bones developed from cartilage. The component parts of each bony system, with the exception of those developed from membrane, showed such involvement.

**Case Report.**—The patient, a man, age 25, was one of ten children. He stated that three of his brothers (not available for examination) had similar tumor masses and deformities, none as numerous or as large as his own. The remaining brother and his five sisters showed no visible evidence of the disease. There was a history of similar tumors in the father, but none had occurred in the mother, nor in the older generations of the family, so far as he knew. His first bony deformity was noted by his parents when he was one year old. At the age of 11, he was admitted to the Children's Hospital, the record of which showed that in June, 1925, bony tumors were removed from the left outer malleolus and from the lower end of the left ulna. Microscopic examination confirmed the clinical diagnosis of benign osteochondroma. According to the record, roentgenologic examination at that time showed multiple exostoses of nearly all the long bones (slides). The metacarpals, the metatarsals, and the phalanges showed the same type of growth, the total number of tumors being 91.

# TRAUMATIC OSTEOMYELITIS: THE USE OF SKIN GRAFTS—PART II\*

## SUBSEQUENT TREATMENT

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THE INITIAL ARTICLE of this series<sup>1</sup> presented the technic and results obtained in skin grafting to hasten healing of the saucerized osteomyelitic wound. The procedure outlined consisted of thorough removal of all involved bone and soft tissue, application of a pressure dressing, and, four days later, skin grafting the resulting granulating wound. In a representative group of cases the results were: 24 per cent excellent, 28 per cent good, 24 per cent fair, and 24 per cent poor. Only in the last group did skin grafting have to be repeated in order for healing to pursue a more rapid course than otherwise could have been expected.

Healing of the osteomyelitic wound in this fashion leaves one with the problem of subsequent treatment of the patient. Obviously, two courses may be pursued—that of no further treatment, and that of replacing the free skin graft in some way. What follows is based on an analysis of the fate of 126 free skin grafts employed to heal saucerized osteomyelitic wounds (Table I). In some instances of failure two or more grafts were applied successively to the same wound.

*Discharged with Free Graft Intact.*—The vitality of free skin grafts is threatened on every hand. The thinner the graft and the poorer the initial take, the greater is this tendency. Congestion, attended by capillary extravasation and edema formation, favors activation of latent infection either primarily, or secondarily through the medium of peripheral phlebothrombosis and thrombophlebitis. Either pure congestion, or infection activated thereby, takes its toll of grafts. Impaired venous return, temporary or permanent, is the rule on resuming ambulation after the osteomyelitic wound has been healed by free skin grafting. Irritant effects of dirt, even on normal skin, need only be mentioned to be appreciated. Depleted in accessory organs, split-thickness grafts are highly sensitive to irritants. Poorly aerated in cavities, opposing skin-grafted walls coming into contact are prone to maceration and smegma formation. Unfavorable hygiene is avoidable in proportion to the visibility and accessibility of the skin graft, granted the patient's zeal for cleanliness. We have undoubtedly discharged some patients with free graft intact, who would have been better off had replacement been performed.

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\* Read before the Fifty-seventh Annual Session of the Southern Surgical Association, December 4-6, 1945, Hot Springs, Virginia.

SKIN GRAFTS IN OSTEOMYELITIS

TABLE I

FATE OF 126 HEALED DERMATOME GRAFTS IN SAUCERIZED OSTEOMYELITIC WOUNDS

Not replaced.....	28
Replacement.....	98
By abdominal tubed-pedicles.....	47
Successful.....	6
Failures.....	4
Incomplete.....	27
Planned.....	10
By direct abdominal pedicles.....	13
Successful.....	12
Failures.....	1
By crossed-legged pedicles.....	11
Successful.....	7
Failures.....	4
By local pedicles.....	13
Successful.....	5
Failures.....	8*
By excision and closure.....	6
Successful.....	5
Failures.....	1
By excision, muscle transplant closure.....	4
Successful.....	1
Failures.....	2
Undetermined.....	1
By excision with iliac chip implants.....	10
Successful.....	2
Failures.....	8

\* Includes cases with iliac bone implants.

TABLE II

NONCAVITIES: METHODS OF REPLACING DERMATOME GRAFTS

*Comparison of various site—coverage combinations*

Coverage

Site	Local Closure	Local Pedicle	Open Pedicle	Closed Pedicle	Total
	<hr/>	<hr/>	<hr/>	<hr/>	<hr/>
Arm	2 <hr/> 100		1 <hr/> 100	1 <hr/> 100	4 <hr/> 100
Forearm			10 <hr/> 80	1 <hr/> 0	11 <hr/> 72.7
Thigh					
Leg	1 <hr/> 100	8 <hr/> 86.5	11 <hr/> 72.7	3 <hr/> 66.66	23 <hr/> 73.9
Pelvis	3 <hr/> 66.66				3 <hr/> 66.66
Total	6 <hr/> 83.3	8 <hr/> 86.5	22 <hr/> 69.5	5 <hr/> 60	Grand Total 41 <hr/> 75.6

Key

No of Cases
<hr/>
% Success



*Replacement of Graft.*—Replacement of free grafts has been effected in a number of ways. The most obvious and simplest is that of excision of the graft and closure of adjoining tissue. Hereafter this technic is referred to as *local closure*. The greater the proportion of soft-tissue involvement to bone involvement, and the less the ratio of width of the original wound to the cir-

FIG. 1-A

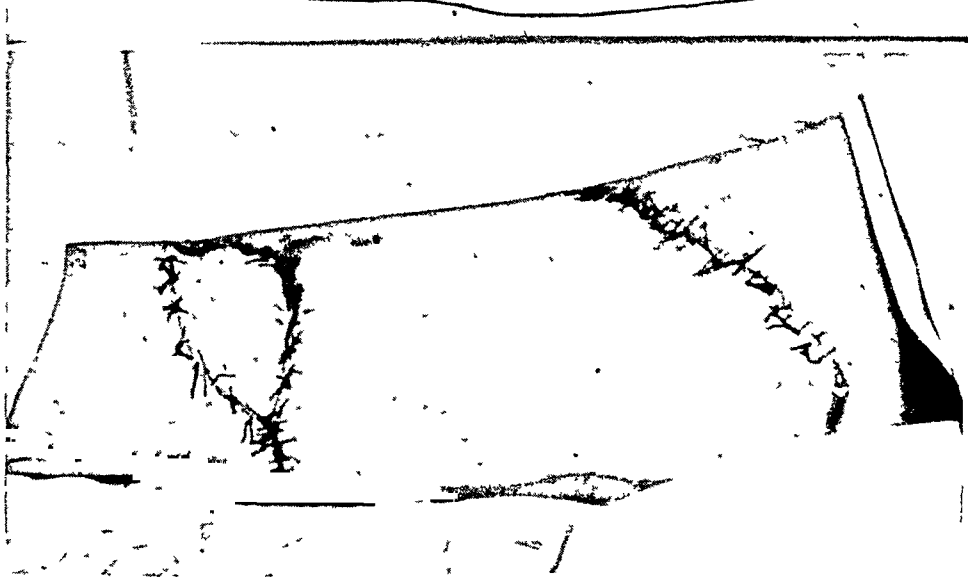
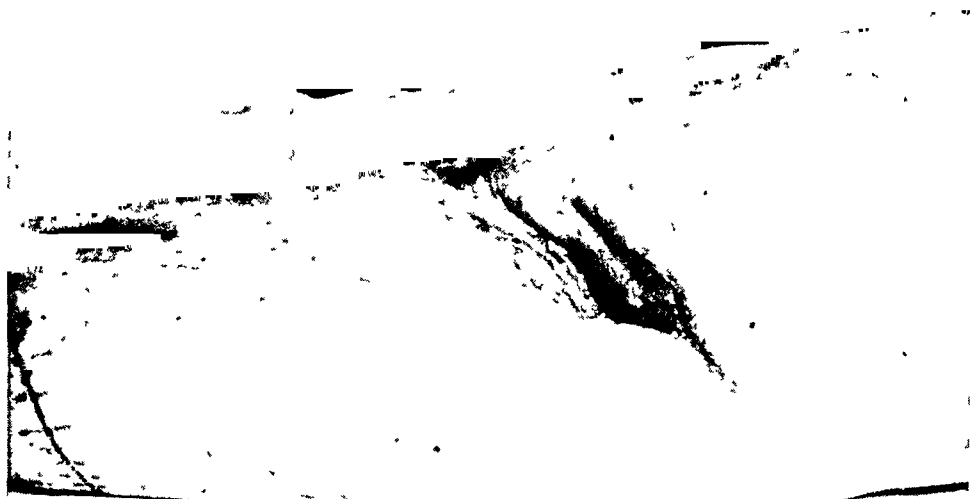


FIG. 1-B

FIG. 1.—(A) Local pedicle. (B) Iliac chips were introduced as fillage coincident with resection of free graft, shift of local pedicle, and skin grafting the newly denuded donor gap. Failure resulted.

cumference of the part involved, the more apt is this method of replacement to succeed. Superficial closure is often the minor problem. Obliteration of deep dead space incident to bone and soft-tissue loss challenges one's ability to bring into play a technic satisfying basic principles of surgery. To the extent of

FIG. 2-A

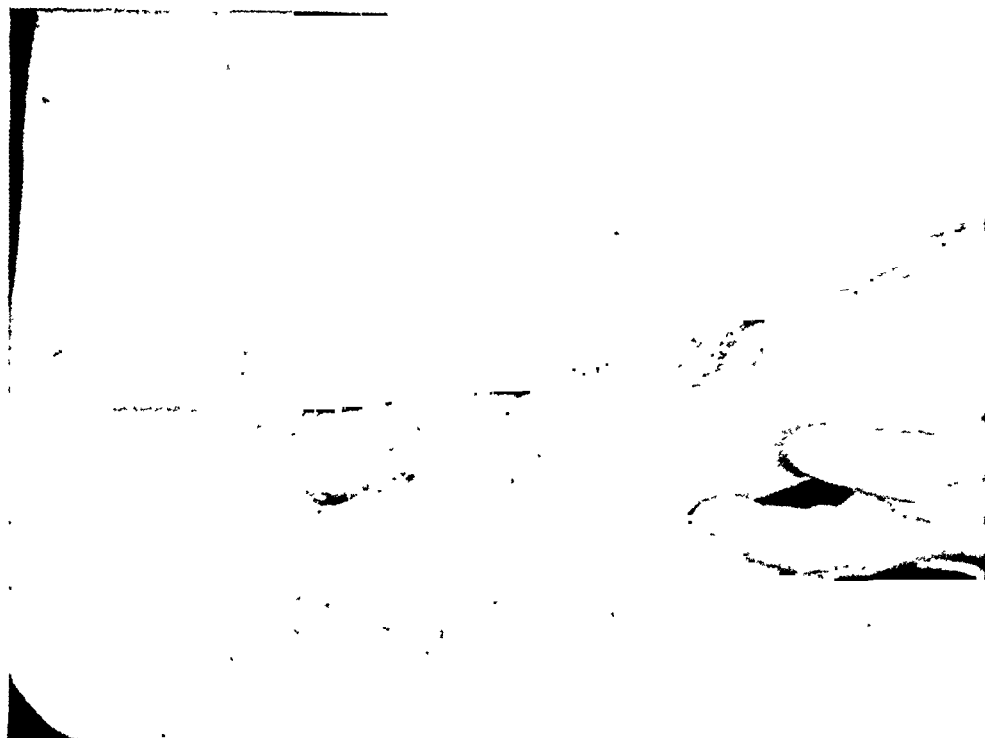


FIG. 2-B

FIG 2.—(A and B) Skin graft for replacement and open pedicle in place. Note the following: Cavity existing required no fillage for dead space; scar wide because of tension; scar of partial severance of flap preliminary to final application—only rarely necessary in abdominal pedicles and not so in this instance.

FIG. 3-A



FIG. 3-B

FIG. 3.—(A) Open pedicle. This cross-leg pedicle, based distally, was used to replace a dermatome graft.  
(B) Resulting donor site and replacement shown.

success in solving the problem of dead space, results are good. Sometimes local closure of *skin only* is effected, and other technics are employed for filling dead space.

Relaxing incisions long have been employed to permit tensionless closure of wounds. The double-pedicle skin flap shifted from local sources to effect closure is the next logical step. Combined with skin grafting of the resulting denuded area, it has been employed in a number of instances. If the flap be single-pedicle, perhaps having been prepared in advance, it will fall more readily into superficial dead space. Again, the site from which the pedicle was shifted may be filled in by free skin graft. This is sometimes referred to as a



FIG. 4.—Closed pedicle. Advantage over direct abdominal pedicle lies in cleanliness of former.

rotation flap. For the purposes of this discussion, each of the above procedures is considered a local pedicle (Fig. 1).

A free graft too large for the above methods may be replaced in the upper extremity by a direct abdominal pedicle,<sup>2</sup> and in the lower extremity by a single-pedicle cross-leg<sup>3</sup> flap. Either of these methods (Figs. 2 and 3) is referred to hereafter as an *open pedicle*.

Where for any reason the free graft cannot be replaced readily by any one of the above means, a tubed-pedicle may be employed, or resort may be had to a "paddle" extension of a tubed-pedicle. These methods are referred to below as *closed pedicles* (Figs. 4 and 5).



FIG 5-A



FIG 5-B



FIG. 5-C

FIG. 5.—(A and B) Late steps in transference of tubed-pedicle to replace a free graft lining a cavity. Fat transplanted with the tube was used to fill potential dead space within the cavity. (C) Healing nearly complete. Ulceration from pressure of dressing over bony prominence.

Replacement problems fall into two groups—those in which the free-grafted surface is flat (Table II) ; and those presenting a cavity (Table III). In the former, one has but to satisfy the precepts of plastic surgery, and success is a foregone conclusion. In the latter, the hazards attendant upon technical inability to perform good skin plastic surgery are increased by the risk attendant upon introduction of material to fill the cavity. We shall refer to the skin as “coverage,” and to the additional material required for cavity obliteration as “fillage.”

As might be anticipated, our results have been in proportion to the complexity of the surgical problem presented, and to a lesser extent to the vulner-

TABLE - III

- C A V I T I E S -  
 METHODS OF REPLACING  
 DERMATOME GRAFTS  
 COMPARISON OF VARIABLE  
 COVERAGE - FILLAGE COMBINATIONS

C O V E R A G E					
	LOCAL CLOSURE	LOCAL PEDICLE	OPEN PEDICLE	CLOSED PEDICLE	TOTAL
F I L L A G E	ILIAC BONE CHIPS	3 66.66	5 20	2 0	10 33.3
	FAT			3 100	3 100
	MUSCLE PEDICLE	6* 66.66	1 100		7 71.4
	TOTAL	9 66.66	6 16.66	5 60	GRAND TOTAL 20 55

KEY  
 No. of CASES  
 % SUCCESS

\* INCLUDES 2 LESIONS TREATED BY  
 SECONDARY CLOSURE WITH MUSCLE  
 TRANSPLANT AS FILLAGE ...

ability of blood supply inherent in the coverage selected. Table I illustrates the type of coverage applied to various anatomic locations when cavities were not a problem. The direct abdominal pedicle flap has been a most dependable procedure. The margin of safety appears greater in this method than in any other. After transfer of relatively large abdominal pedicles, closure of the resulting wound is possible.

The technic of cross-leg flaps, as described by Ghormley,<sup>3</sup> has proved reliable in our hands. The importance of removing fibrotic tissue from the deep surface of the pedicle at the time of its transference cannot be overemphasized. Of still greater importance is application in advance of plaster encasement, both to the donor and to the recipient leg. Through appropriate windows, surgery

for transference of the flaps is performed. When this is completed, struts of plaster and wood bind the legs together. Thus, one prevents twisting, turning and tension so fatal to pedicles. Although we have received informal reports of difficulties from applying a dermatome graft beneath the pedicle prior to its transfer, this procedure has been most gratifying to us and has led to no difficulties with either the dermatome graft or the pedicle itself.

Attempting to force by pressure or suture any type of pedicle graft into a cavity invites disaster. In dealing with cavities, two groups of substances have chiefly been employed for filling dead space: (1) Bone as free graft. (2) Locally available substances, principally fat and muscle, as pedicle grafts. The former has found more extensive usefulness. Knight and Wood<sup>4</sup> have reported considerable success with its employment, and since it is most often bone substance which is to be made up, it has been the logical material to use. When readily available, and when no need existed for increasing bone strength, pedicle grafts as fat or muscle have been employed in several instances.

Our success with bone as fillage has been deplorably poor. Iliac chip replacement was employed in four cases of related type not included in this series, in each instance with success. In one, simultaneous saucerization and filling of the resulting cavity with iliac chips was performed, with *per primam* healing resulting. In a second, a local pedicle covered iliac chips introduced four days after saucerization and packing of the wound with plain gauze. Again healing was prompt, without drainage. In the remaining two, iliac chips were grafted into recently healed osteomyelitic wounds, with general and local recovery uneventful. Technic of bone surgery employed in the two groups of patients was comparable. Success in the latter four patients presenting comparable risk of infection, suggests that our failures are not explainable on the basis of inadequacies in technic of bone surgery.

Faced with an overwhelming proportion of failures when iliac bone chips were used as replacement, we have employed increasingly many abdominal tubed-pedicles. Thus, we can introduce fat into the cavity as fillage simultaneously with skin coverage. Results have been excellent in replacing by this means free skin grafts occupying bone cavities. Grafting bone into the cavities later should present no special risk.

At present, Captain E. R. Zaglio, a member of the Orthopedic Section at this hospital, is investigating the applicability of physiologically inert foreign substance as fillage. Thus far, there appears to be some promise in this method.

#### CONCLUSIONS

A considerable proportion of free skin grafts employed to hasten healing of saucerized osteomyelitis wounds require no replacement. When outlook for permanence of a free graft is otherwise good, one should use skin thick enough to contain skin accessories. Little difficulty will be met by those experienced in plastic surgery technic in replacing the skin grafted on a flat surface. Replacement of free skin grafts lining cavities has posed a considerable problem to us. We have failed where others have succeeded in using iliac bone chips to fill

cavities occupied by a free graft undergoing replacement. The search for a substitute or intermediary procedure is being continued.

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## REPAIR OF BONY DEFECTS ASSOCIATED WITH OSTEOMYELITIS\*

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CHRONIC, localized hematogenous osteomyelitis continues to be a difficult surgical problem. Infection is harder to control in bone than in other connective tissues. Bone is rigid, its vessels cannot contract or expand and its cavities do not collapse. Even if infection has finally been arrested, the surrounding bone is abnormal because of diminished circulation, increased density, loss of valuable organic material and isolated tiny cavities containing dormant organisms.

The advent of chemotherapy and the development of new procedures in the management of compound fractures during the war gave rise to the hope that osteomyelitis might be eliminated. As the end-results of treatment become better known, it is evident that chemotherapy is not the entire answer to the problem and that well-directed surgical measures must continue to be our mainstay for the treatment of chronic osteomyelitis.

At the Tulane University School of Medicine and Charity Hospital in New Orleans a project, under the direction of the Subcommittee on Wounds and Burns of the National Research Council, was undertaken to evaluate various surgical procedures for the repair of bony defects associated with chronic osteomyelitis. The objects were to promote union of compound fractures with bony defects and infection and to obtain closure and healing of the infected bony cavities in chronic hematogenous osteomyelitis.

At the outset certain essential differences between localized and hematogenous osteomyelitis were recognized. The localized type associated with compound fractures usually occurs in the shafts of the long bones in adults. Because of the fracture, perfect immobilization is impossible and motion of the fragments prolongs the infection. Frequently, small fragments have been lost leaving an infected bony defect. In the chronic stage the bone-forming elements have ceased to function, the ends of the fragments are relatively avascular, the marrow cavity is sealed and the periosteum is destroyed. The process, however, is confined to the immediate site of fracture, and the remaining portions of the shaft and the extremities of the long bone are approximately normal.

In contrast, chronic hematogenous osteomyelitis is seen most often as extensive involvement of most of the shaft and one extremity of a long bone in children. Frequently, there are multiple foci and flat bones may also be

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\* Read before the Fifty-seventh Annual Session of the Southern Surgical Association, December 4-6, 1945, Hot Springs, Virginia.

involved. The lesion in adults is usually a recurrence of the old childhood infection but may occur as an initial attack. In the latter instance, infection is usually in the shaft of a long bone and the course of the disease is not the same as that observed in childhood because of the difference in the structure and blood supply of adult bone. However, the appearance of the bone in the chronic stage is much the same as in the recurrences following an initial attack in childhood.

The microscopic sections of bone from localized osteomyelitis cannot be differentiated from those of the hematogenous type. The problems are essentially the same except for the sharp limitation of the bone reaction in the localized variety. In both types there may be general depletion, extensive scar formation and diminished local blood supply. The bone itself is often devoid of normal periosteum and is brittle, and relatively avascular. Granulating cavities draining poorly or containing sequestra are common. Mixed infections are the rule rather than the exception.

The sulfa drugs and penicillin are usually effective against the staphylococci and streptococci present in the bone cavities, but their effectiveness is impaired by diminished blood supply to the part and by the presence of mixed infection, cavities and sequestra. Chemotherapy, therefore, plays a limited rôle in the elimination of infection and final healing and its use must be supplemented by surgical measures to remove dead bone, flatten cavities and obtain good soft part coverage of the remaining bone. In addition, in compound fractures it is essential to immobilize and fix the fragments and provide some stimulus for new bone formation.

The surgical measures employed have been simple modifications of recognized standard procedures for dealing with the soft-parts and bone. Complete removal of the scar and sinus (when present) is the first step. The deep as well as the superficial portions must be widely excised until healthy skin, fascia and muscle are encountered. In like manner, the dense, sclerotic, "scarred" bone should be removed with a chisel until healthy, bleeding bone appears. After dead bone and fibrous tissue filling underlying cavities have been removed, the cavity should be shaped to the best possible advantage for coverage with soft-parts. It is always desirable to cover the raw bone with muscles and full-thickness skin; if both are not available, full-thickness skin may suffice. In order to cover the area adequately it is often necessary to split the fascia over adjacent muscle compartments and permit the muscles from either side to bulge out over the bone. In some cases it is necessary to sacrifice a muscle by dividing it at the musculotendinous junction and freeing the belly far enough to permit it to swing as a pedicle graft into or over the defect. In freeing the muscle for this purpose its blood and nerve supply must be carefully preserved.

Skin coverage usually can then be accomplished by undermining and sliding the skin on either side. If this cannot be done without tension, the undermined skin may have to be split at some distance from the wound margins or made into a pedicle graft on one side. Again, care must be exer-

cised to retain abundant blood supply to the flap or pedicle by observing the ratio of three to one between length and width of the graft and planning it to retain a sizable nutrient vessel. The principle to be observed throughout the operation is to get healthy bleeding bone surfaces covered with healthy, bleeding soft parts but without tension.

Immediate closure without drainage is followed by primary healing in about 90 per cent of the cases, but only about 60 per cent remain permanently healed. Failure to heal is attributable to incomplete removal of scar and sclerotic bone (which is sometimes impossible in cases of chronic hematogenous osteomyelitis), to inadequate blood supply to bone and soft-part coverings, or to too great tension on the skin margins. Recurrence of infection is usually prevented if adequate coverage and good blood supply can be preserved.

If the infected bone cavity is large enough and so located that it weakens the bone for weight bearing, consideration must be given to filling the cavity with a bone graft and obtaining adequate soft-part coverage thereafter. Knight and Wood<sup>1</sup> have apparently solved this problem in cases of localized osteomyelitis by a three-stage procedure. In the first stage sequestra are removed and the cavity is prepared for the second stage, *viz.*, application of a split-thickness skin graft, and a third stage which includes excision of the split-thickness graft, filling the cavity with bone chips and covering them with full-thickness sliding or pedicle graft of skin. Their early results in 23 published cases have been excellent. Application of a similar procedure to cases of hematogenous osteomyelitis may present a greater problem but certainly should be tried.

Old, compound fractures with nonunion and draining sinuses have been treated while still draining by excision of scar and sinus and performance of a step-cut procedure on the bone ends followed by closure. Internal fixation is not used. The inch of shortening is not a serious disability and the resultant laxity of the tissues caused by shortening usually permits closure of the skin without tension. In the leg, osteotomy and overlapping of the fibula is usually a necessary adjunct.

Other cases with loss of substance, 1 to 3 cm., have been treated in the presence of active infection by an approach to the lateral aspect of the tibia that is some distance from the scar and sinus. In such cases the periosteum and muscles are simply pushed laterally and a long graft taken from the opposite tibia is forced alongside between the lateral face of the tibia and the fibula. It may or may not be fastened to the tibia with screws. The sinus and scar are not disturbed. Dr. H. Pagé Mauck<sup>2</sup> recently demonstrated a number of cases treated by this procedure with resultant closure of the sinus and bony union in a high percentage. Various operative procedures, as previously described, have been used in 43 cases of chronic osteomyelitis of long bones. In all of these penicillin was given two to three days prior to operation and for seven to ten days afterwards. There were 21 cases of localized osteomyelitis of which 80.4 per cent healed *per primam* but only 61.8 per cent remained healed after 5 to 12 months. Sufficient time has not

elapsed to give the percentage of cases in which bony union has developed. There were 22 cases of hematogenous osteomyelitis (nine tibias, eight femurs and five humeri). Of these, 81 per cent healed primarily but only 63 per cent remained perfectly healed after 5 to 12 months. Analysis of failures to heal in both groups indicates that incomplete removal of scar and bone and too great tension in making skin closures were the important causes.

#### SUMMARY

Well directed surgical measures to remove dead bone, flatten cavities and obtain good soft-part coverage of the remaining bone continue to be our mainstay for the treatment of chronic osteomyelitis. Penicillin and the sulfonamides play only a limited rôle in the elimination of infection and final healing. Of 21 cases of localized osteomyelitis treated by various surgical procedures supplemented by chemotherapy, 80.9 per cent healed *per primam* but only 61.8 per cent remained healed after 5 to 12 months. Of 22 cases of hematogenous osteomyelitis, again, 81 per cent healed primarily and 63 per cent remained healed after 5 to 12 months.

#### REFERENCES

- <sup>1</sup> Knight, M. P., and Wood, G. O.: Surgical Obliteration of Bone Cavities Following Traumatic Osteomyelitis. *J. Bone & Joint Surg.*, 27, 547-556, October, 1945.
- <sup>2</sup> Mauck, H. P.: Personal communication.

DISCUSSION.—DR. WILLIAM DARRACH, New York, N. Y.: I should like to express my deep appreciation for the invitation to be present at this meeting. The reputation of the Southern Surgical Association for advancement of knowledge as well as for delightful entertainment has been outstanding for many years, and they have more than lived up to this reputation.

I should like to emphasize one point brought out that we as civilians have to face, and the men in the army and naval hospitals have to face; that is, the filling in of defects following gunshot or other wounds of the lower extremities, more especially the tibia. There is an underlying principle they have mentioned, which Champ Lyons brought out several years ago, and others have since—that is, the preparation of the patient prior to operative work in the final stage of treatment to fill in these defects. I think one of the most graphic descriptions of preparation of the patient comes from the Bible:—

"A sower went out to sow his seed; and as he sowed some fell by the wayside; and it was trodden down and the fowls of the air devoured it. And some fell upon a rock; and as soon as it was sprung up, it withered away, because it lacked moisture. And some fell among thorns; and the thorns sprang up with it and choked it. And other fell on good ground, and sprang up, and bore fruit an hundred fold. He that hath ears to hear let him hear."

I think we can also get good advice from our wives as they work in the garden; they prepare the bed before they put in the seed. It seems to me if we are going to prepare any form of bone graft or filling-in of a cavity, we must pay attention to preparation of the patient from both a general and local standpoint. It is interesting to see how reparative bone processes will improve after a few transfusions; building up the patient from all points of view, general as well as local preparation, will determine very largely the success of our efforts.

MAJOR-GENERAL NORMAN T. KIRK, Washington, D. C.: I am always glad of an opportunity to express my gratitude to the medical profession for what it has done to save the lives of the men who fought this war. I am particularly glad to be able to say this to a group of specialists, for specialists were utilized in this war as they never were utilized in previous wars. The Medical Corps, like other branches of the Army, was

chiefly made up of civilian components. We of the Regular Army formed the nucleus of the Corps, it is true, but the war was fought and won by civilians, and the outstanding record of the Medical Corps was made possible by the civilian physicians who constituted the great majority of its personnel. Incidentally, I am not unmindful of the contribution made by the physicians who did the work at home. I realize, very fully, how greatly their task was increased by the withdrawal of so many of their number into the Service.

Wounded casualties in the Army amounted to approximately 571,000, of whom about 360,000 were returned to duty overseas. About 25,000 of our wounded died, approximately 4 per cent. I am told on good authority that the German losses in this category amounted to 8 per cent, and that during the winter campaign of 1944-45 about 13 per cent of their wounded died as the result of their injuries.

In my own mind there is no doubt why the percentage of American deaths from wounds was so much lower than the German percentage. I was in North Africa in April, 1943. I was in Italy the following year. What happened in the Medical Corps between those two dates is the explanation.

On the occasion of my first visit to the Mediterranean Theater of Operations, every medical officer in the Corps was treating patients according to his own plans and policies. Some of the methods were very good. Others, to put it bluntly, were very poor. On the occasion of my second visit, every patient in the Theater was being treated according to the definite regimen instituted under the leadership of Colonel Churchill. Phases of military surgery and the missions of each echelon in respect to them had been clearly established. The first phase, initial surgery, was performed near the Front lines. The second phase, reparative surgery, was performed in the Base Hospital behind the lines. The third phase, reconstructive surgery, was performed in the Zone of Interior.

It was this system of surgery, strictly adhered to, which gave the American Army the lowest percentage of deaths from wounds ever achieved in any Army. Before this method was developed, to give you a single illustration, the incidence of osteomyelitis following compound fractures was relatively quite high. Initial débridement was often imperfectly done, and delayed wound closure was infrequently practiced. Patients were put in plaster and they arrived in this country with infected, malodorous wounds, the end-result of which was deformity.

Then the plan was changed. Initial surgery was thoroughly carried out in Field and Evacuation Hospitals. Primary closure was not permitted. It was impractical to secure precise reduction of fractures in the Forward areas, and the attempt was therefore not made. Instead, plaster designed primarily for transportation from the Forward Hospital was applied and the patient was transferred to the General Hospital in the Base. Once he reached the General Hospital, accurate reduction was achieved by manipulation or skeletal traction. The compounding wounds, if they were clinically clean, were closed by suture or skin graft, usually within five to ten days after wounding.

Patients were held in the Base Hospital until early callus formation would prevent displacement of their fractures during transportation. Those with fractures of the femur were held for eight to ten weeks, and sometimes longer, in skeletal traction. Then, in a lag-period, when no definitive surgical procedure was necessary, they were transported to the Zone of Interior.

Let me call your attention to several special points. In the first place, please note that it was the gross appearance of the wound which determined the time for delayed suture or skin graft, not bacteriologic studies. I yield to no one in my admiration for the bacteriologist in his place, but I thank God he was not available for use in this connection.

In the second place, while great advances have been made in reconstructive bone surgery, I do not myself classify a sliding bone graft of the tibia among them. I sometimes hear surgeons remarking that they can perform such grafts and "get away with them." Perhaps so, though not in most cases, and I do not believe, regardless of the outcome, that this method represents good surgery. Furthermore, we learned in the course of the war, and it is regrettable that we had to learn it over again at the patient's expense—we knew it 25 years ago—that any kind of graft is useless unless it is put into a properly prepared bed.

Finally, let me say a word about chemotherapy. We owe much to the studies of the National Research Council in this field, and the systemic administration, first of the sulfonamides and later of penicillin, undoubtedly saved many lives and made much

extensive surgery possible. I think we can hope for even more remarkable results in some diseases from streptomycin. But I do want to emphasize that it was good surgery which saved lives. The thorough excision of devitalized tissue was absolutely essential. Chemotherapy was merely an adjunct. The early reports from Pearl Harbor completely misled us. They were not duplicated in a more extensive experience. We promptly learned that dusting a wound with sulfanilamide, or giving sulfanilamide by mouth in the form of pills, did not permit a disregard of sound surgical principles. That was another thing we learned the hard way, but eventually we learned it.

All our badly wounded soldiers—between 260,000 and 280,000 of them—have been brought back to the General Hospitals in this country. The men with osteomyelitis, the men with bilateral amputations, the men who need multiple plastic operations and multiple hand surgery and other equally serious procedures have come home from the war. Their need now is primarily for specialized treatment. The fighting war is over, but the Medical Corps has still a job to do. That it will be finished with the same competence with which it was begun, I have not the slightest doubt.

DR. DUANE CARR, Memphis, Tenn.: Over a number of years it has been my privilege to observe a reasonable number of patients with osteomyelitis of the bones of the thoracic cage. It is a problem on which Dr. John Alexander and I wrote some 10 or 12 years ago, and at that time we advocated adequate surgical débridement of the tract followed by primary closure in those cases of tuberculous osteomyelitis uncomplicated with pyogenic infection. However, many of these cases of osteomyelitis of the sternum, ribs or clavicle were primarily tuberculous but complicated with pyogenic infection, following incision and drainage of the original abscess, resulting in a chronic mixed infection.

In our 46 cases a fairly large percentage of those treated with primary closure reopened. Many of our earlier mistakes, I believe, have now been overcome. Our practice now is the complete excision of all infected tissue and bone followed by primary closure with a pressure dressing, even in the mixed infected cases. Penicillin before and after operation is a helpful adjunct, but we found our principal mistake formerly was in failing to carry out a more complete excision. Osteomyelitis of the thoracic cage complicated by tuberculosis has a tendency to develop sinuses boring through adjacent tissue and leading to other abscesses at some distance from the site of the original infection. Many of these sinuses are so small as to escape detection in the operative wound. I have, therefore, routinely used the injection of one per cent methylene blue under gentle pressure before the excision is begun and, to be complete, the excision must include all stained tissue. A spot less than one millimeter in diameter may be a sinus leading to an abscess elsewhere or even osteomyelitis of adjacent bony structures.

The use of methylene blue, the complete excision of all diseased tissues, primary closure without drainage, a pressure dressing, and penicillin before and after operation, have resulted in 100 per cent permanent closure in the limited number of patients so treated in the past two years.

DR. CHARLES S. VENABLE, San Antonio, Texas: I have enjoyed the very scholarly presentation of Doctor Caldwell and am for once not in any disagreement. I think, however, there are some few very salient factors that may be taken in their order in doing secondary rearrangement and rehabilitation following destructive osteomyelitis. General Kirk "rang the bell" when he said you cannot expect sulfa and penicillin to take all the cockroaches out of the kitchen. It takes plenty of good surgery, as we learned in the last war. Let us grant this has been done and we come to the defects following osteomyelitis. I think we must give the time-element a sufficient waiting period to know that no further necrosis is beginning in the bone ends. That gives an expression of the blood supply, because if this is insufficient union will not take place. When this has been decided—the condition of the tissues and even spots of regeneration of bone—the remaining periosteum must be removed and the bone ends denuded entirely to assure the blood supply to both ends of the graft. This must be firmly fixed, because if there is movement fibrosis will occur at one or the other end and union will not take place. I think soft-tissue closure is almost as important because, after all, blood supply is what it takes; closure of the soft-tissue so closely and completely about the graft that it may pick up blood supply between its ends. A dead space there is an exposure to defeat.

DR. ROBERT W. JOHNSON, JR., Baltimore, Maryland: My introduction to chronic osteomyelitis took place at the hands of Doctor Halsted. In those days we were sterilizing these cavities after radical excision and saucerization by pure carbolic acid, followed by alcohol, and lavage with at least ten gallons of bichloride solution. With his meticulous technic the field was cleaned and redraped, and we transferred to an entirely clean instrument table and set-up. Even after this heroic procedure the blood clot would break down and the wounds show the same organism as before. That experience sold me on the idea that the wound of an osteomyelitis could not be sterilized by any local method, and later experience with Dakin's solution, maggots, sulfa compounds, and penicillin locally have only served to confirm this. We have, however, an entirely new help in systemic chemotherapy, working on the "patient-side" rather than the "doctor-side" of the wound. This is the greatest advance that has been made, and this change in method and point of attack has been shown splendidly by the essayists.

I think that Doctor Caldwell's slides on the pathology, with which he introduced his remarks, are the crux of the situation. He shows that he is dealing with the pathologic tissue and not the cavity. The cavity is one thing, the pathologic tissue in the wall of the cavity is another, and this latter is what we must keep in primary consideration. We are dealing with tissue, ill-supplied with blood at best, which has little chance to become hyperemic, and with bone trabeculae and scar-filled spaces it has little power of healing. This is why bone cavities differ from other scars in healing ability. New blood supply is simply unable to reach the site of the disease. While this is true in acute osteomyelitis, it is ten times more so in the chronic type. All the measures that have been suggested are of value—grafts of skin, flaps, muscle flaps, *etc.*, in that they reduce the area to be filled in and/or bring with them new vascular supply to aid in the process. Major Kelly's cases, which we were privileged to see yesterday, are even more convincing than his excellent paper of today.

DR. FREDERIC W. BANCROFT, New York, N. Y.: I would like to emphasize the difference in the healing of fractures of bone and ordinary connective tissue. Bone consists of two elements: a cellular element and a matrix which has low metabolic needs and can persist for a considerable time without the presence of cellular elements. When a bone transplant is imbedded, sections of this bone two or three weeks after operation will show the absence of osteoblasts in the bone spaces. As time goes on, if graft is to succeed, there will be revascularization through the vessels entering the Haversian canals and about these vessels will appear numerous bone cells in the canaliculi. If revascularization does not occur in the bone graft and cells do not reappear, the bone eventually atrophies, or if infection be present it is cast off as a sequestrum. I believe that we see the evidence of bone atrophy in late fractures of the graft when the transplant is not laid in a vascular bed.

These observations are important clinically because they show us that we must place a graft in an area free from scar tissue and infection if we expect the graft to persist and become again living bone, which occurs by a gradual process of creeping replacement.

#### EDITORIAL ADDRESS

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## REPAIR OF SURFACE DEFECTS OF THE UPPER EXTREMITY\*

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THE RECENT WAR has fostered the recognition of reconstructive surgery of the hand and upper extremity as a special problem. This is a result of the large number of hand casualties, with injuries involving skin, bone, joints, tendons and nerves, and the realization that the treatment of these injuries does not primarily fall into the field of any of the previously recognized specialties. Appreciation of this fact by the armed services has resulted in the formation of Hand Centers, where there has been a dissemination and correlation of knowledge of bone, nerve and tendon repair and of plastic surgery as it relates to the hand. This concept was formerly applied in only a few clinics throughout this country. The experience gained in handling a large number of hand injuries has resulted in improved technics and in some new procedures.

The repair of surface defects of the upper extremity demands a knowledge of the whole hand problem. Evaluation of the type of replacement requires a definite plan for the future care of the individual patients and a familiarity with the various plastic surgical technics involved. The operating surgeon should understand the underlying pathology and be capable of preparing for, or doing, whatever deep repair is necessary at the time of surface replacement. Not only is time saved but a better end-result is frequently obtained, for instance earlier nerve suture. Fewer operative stages with accompanying trauma and periods of joint immobilization result in better function, other factors being equal.

The hand and arm should be splinted in the position of function at the time of the original injury. Mobilization of the unaffected parts should be maintained, and complete mobilization obtained as early as healing will permit. Damaged or deinnervated muscles should be supported in a neutral position to prevent stretching and to prevent contracture of opposing muscles and

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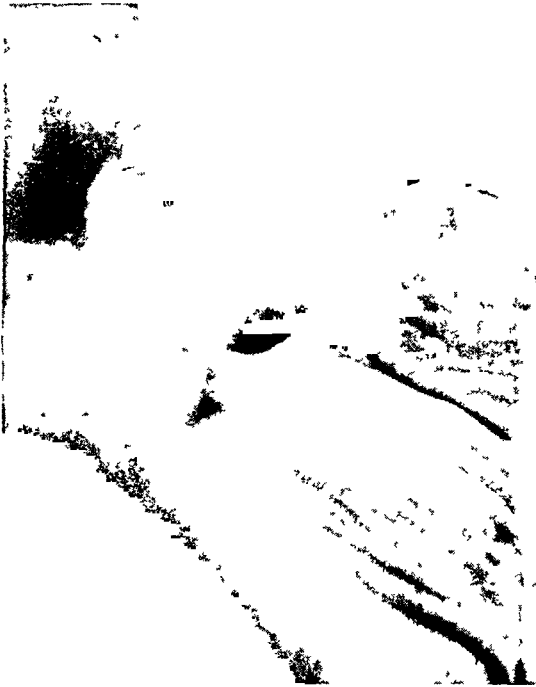


FIG. 1.—Sensitive neuromatous nodule formed from divided digital nerve in amputation scar. Cure was obtained by resection of scar, neuroma and two centimeters of digital nerve.



FIG. 2-A



FIG. 2-B

FIG. 2.—(A) Wound of shoulder with loss of skin and insertion of deltoid and resulting subluxation of shoulder and inability to abduct.

(B) Wound closed by undermining completely around the arm and over the shoulder. At the same time the deltoid insertion was sutured to the humerus. Postoperatively, the arm was maintained in abduction.



FIG. 3-A

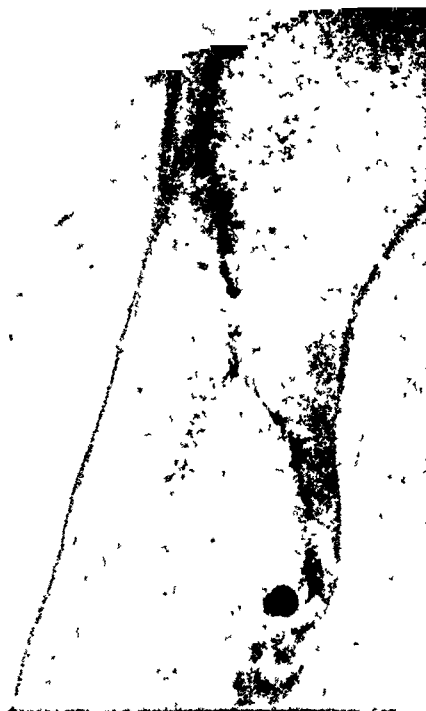


FIG. 3-B

FIG. 3.—(A) Large defect of arm previously covered by split-thickness skin graft which was adherent to the humerus and painful.

(B) Ten days postoperative; following complete excision and closure by extensive undermining of skin and subcutaneous tissue. The edges were approximated under maximum tension by a continuous subcuticular stainless steel wire suture.



FIG. 4.—Postoperative view of rotation flap from posterior axilla used to cover shoulder defect.

tendons. Elevation and a mild pressure dressing on the damaged part prevents edema and circulatory congestion, leading to exudation, additional fibrosis and impaired function. Healing is promoted and less stiffening of the joints results. Open wounds should be kept clean and closed as early as possible by secondary suture, split-skin graft or flap. Selection of the method of closure is based on the final covering desired, though occasionally a thin split-skin graft may be applied as a temporary skin dressing. Clinical observation of wounds of the hand has shown progressive decrease of pain, swelling and joint stiffness as infection is controlled. Improvement is striking with the elimination of the open wound.



FIG. 5-A



FIG. 5-B

FIG. 5.—(A) Flexion contracture of middle finger with division of digital nerve supplying radial side of finger.

(B) Correction obtained by rotation flap and Z-plasty. A nerve graft from the amputated index finger was successfully used to obtain sensation.

The choice of the proper type of replacement depends on the amount of loss and on the requirements for contemplated surgery and ultimate function. In general, if the loss is superficial, adequate replacement can be obtained with a free skin graft, as best illustrated in burns. If the loss involves the deep structure, skin and subcutaneous tissue will be required. This may be as simple as a scar excision or as extensive as a pedicle graft. Most severe war injuries due to shell fragments fall into the latter category.

Complete scar excision is done at the time of replacement. This should include removal of foreign bodies, nonvital bone, and severely damaged tendons which cannot later be used. Wounds of the finger and hand resulting from missiles frequently are allowed to heal secondarily. Digital nerves, when divided, proliferate in these scars, sometimes forming deep, bulb-type neuromata and sometimes growing to the surface where they form smooth,

rounded and frequently reddened elevations varying from pin-point to three millimeters in diameter. These lesions are most frequently found on the ends of amputated fingers and are extremely sensitive to the slightest trauma. Cure is accomplished by removing the neuroma and scar and, if nerve suture is not indicated, a considerable length of the responsible nerve is removed and the end ligated.

Incisions and graft margins are placed so that they do not cross flexion creases and in general conform to Langer's lines of skin tension. Median longitudinal incisions are avoided even to the extent of removing normal skin. Midlateral incisions on the finger and incisions angulated to be parallel or oblique to tension lines and flexion creases are used.

Clean and complete healing is obtained postoperatively before mobilization is begun. When a contracture has been corrected surgically the part is splinted as near full correction as is consistent with optimal healing. Slow and gentle traction after healing completes the correction. This is preferable to expecting a wound to heal well while subjected to tension or motion. Certain less severe skin or deep scar contractures can be adequately corrected by traction alone. Complete hemostasis, a minimal amount of buried suture material and avoidance of trauma at the time of surgery assures better healing and minimizes formation of deep scar. Massive pressure dressings, evenly applied, prevent accumulation of blood and serum, prevent edema and venous congestion, coapt tissue surfaces and help provide immobilization. Fine stainless steel wire has proved very satisfactory for skin closure because it causes a minimal amount of reaction. This is particularly appreciated in a hand prone to excessive perspiration or with impaired circulation and slower healing.

Unhealed wounds in selected cases can be closed by secondary suture. Proper surgical preparation of the wound, including removal of all scar and granulation tissue, is the primary consideration. Foreign bodies, sinuses or sequestra are not necessarily contraindications for early and complete closure of wounds, especially with the control of virulent organisms by chemotherapeutic and antibiotic agents. A wound made surgically clean allows primary healing in the great majority of cases. It is our belief that drugs will not



FIG. 6.—Flap from amputated little finger used to cover defect on ulnar border of hand. (Courtesy Captain Samuel B. Fowler, M. C.).



FIG. 7-A



FIG. 7-B

FIG. 7.—(A) Band contracture at base of ring finger producing flexion deformity.  
(B) Improvement after Z-plasty.

FIG. 8-A



FIG. 8-B

FIG. 8.—(A) Broad, dense keloid with contracture involving wrist and little finger.  
(B) Postoperative view following excision, undermining of edges and multiple Z-plasties.

# SURFACE DEFECTS OF UPPER EXTREMITY

FIG. 9-A



FIG. 9-B

FIG. 9.—(A) Flexion contracture of middle finger secondary to scar in palm.  
(B) Extension and complete flexion obtained by excision of scar, tendon lysis and full-thickness graft.

FIG. 10-A



FIG. 10-B

FIG. 10.—(A) Severe flexion contracture of fingers and web between thumb and index finger secondary to burns.

(B) Early postoperative view of result obtained by relaxing incisions on palmar surface of fingers covered by "three-quarters-thickness" grafts from the medial side of the arm. The web has been deepened and the contracture relieved by Z-plasty and skin graft.

prevent infection if there is more than a minimal amount of nonvital tissue, hematoma, dead space or foreign material.

The method of choice in replacing defects is scar excision with closure by mobilization of the surrounding skin and subcutaneous tissue. This closes the defect with skin of the same type that has been lost and is simpler than most

FIG. 11-A



FIG. 11-B

FIG. 11.—(A) Keloid scar on dorsum of hand with limited flexion of thumb and fingers and flexion contracture of little finger. A thin split-graft had been applied.

(B) Full function obtained following excision of scar, release of contracture and application of thick split-graft.

other procedures. This method is often applicable to relatively large defects of the arm and forearm, less so in the hand because there is less skin for stretching without causing contracture. Extensive undermining, which may encircle the extremity, is supplemented by splitting the superficial fascia to obtain complete mobilization of the skin. A method for testing maximum stretching



of the skin is to pull the margin firmly and note whether the skin is mobile under the finger a distance from the edge. If it is, the skin is prevented from complete stretching by subcutaneous structures. Because the fibrous septa connecting the skin and deep fascia are better developed in the hand than on the arm and forearm, undermining is necessary for closure of even a small defect. Skin may be closed under considerable tension providing the tension is

FIG. 12-A

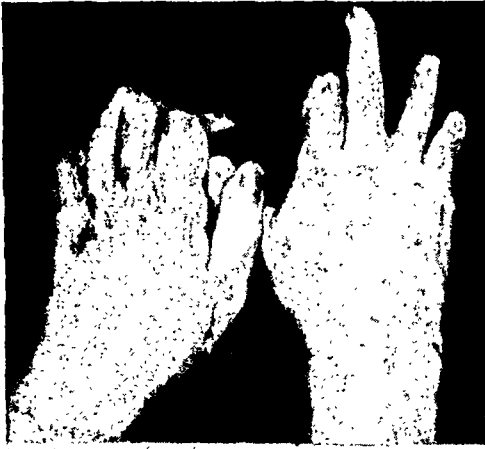


FIG. 12-B

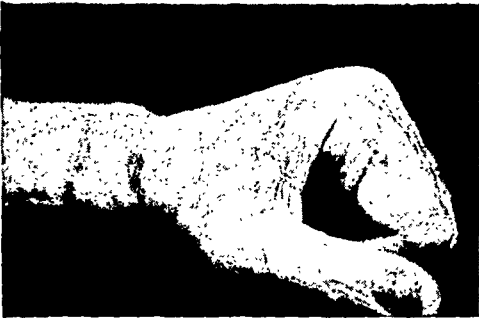


FIG. 12-C



FIG. 12-D

FIG. 12.—(A) Preoperative view of severe burn of hands with subluxation and inability to flex any of metacarpophalangeal joints. Grafts had been applied to the dorsum of the hands.

(B) Early postoperative view of graft over metacarpophalangeal joints of the left hand which was applied at the time of capsulotomy. A Z-plasty was also done to correct a band at the margin of the old graft which limited the motion of the thumb.

(C) Later postoperative view of the left hand showing complete flexion obtained by capsulotomy and skin graft.

(D) Left hand has been corrected. Fingers of right hand in traction to maintain flexion postoperatively following the same procedure.

carried by buried sutures in the dermal layer. The usual concept of the dangers of closing wounds under tension is based upon the use of cutaneous sutures to bring the edges together. Cuticular sutures under tension result in cutting, local impairment of circulation and necrosis with superimposed infection. This results in poor healing and frequently separation of the margins. Accurate approximation of the dermal layer by buried, nonabsorbable sutures (interrupted, inverted subcuticular or continuous subcuticular)

permits closure under maximum tension. Skin closed tightly will be found relaxed and fairly mobile at the first dressing if there is subcutaneous tissue and the skin is not bound down by scar. Additional relaxation takes place for several weeks. This phenomenon allows the closure of an occasional defect by multiple-stage scar excision. Initial stretching as well as subsequent relaxation is greater if the pull is perpendicular rather than parallel to Langer's lines.

Local flaps, in general, are useful for small defects and contractures on the hand and fingers. They offer the advantage of better sensation than skin grafts or pedicles from other parts of the body where sensation is not so well-developed. Rotation, or double pedicle flaps, from the dorsum are useful in the repair of amputated fingers when reamputation and shortening is undesirable. The loss of one side of a finger tip may be nicely corrected by shortening the nail, removal of a small amount of distal phalanx and rotating a flap. There have been no cases, in our experience, in which we have thought that it was indicated to apply a flap from the palm to the fingertip. Double pedicle flaps are useful on the arm or forearm where closure of a wound cannot be effected by undermining. In these cases a double pedicle flap is made by using a relaxing incision parallel to the original wound and free skin-grafting the defect produced. This provides a flap for the original deformity and places the graft on normal tissue.

When amputation of a finger is indicated, a large amount of skin becomes available for use on either the dorsum or the palm. The finger can be split in any vertical plane and the bone and tendons removed. The vessels are preserved. It is possible to use the finger as one flap or to rotate half in one direction and half in another, making one flap available for the palm and another for the dorsum. Finger skin thus used will usually remain viable to the distal joint. With this possible use in mind, fingers should be preserved at the time of extensive injury even though amputation will be indicated later.

Z-plastic procedures allow the release of contracture in one direction by utilizing tissue from the other direction. They are especially useful for band-type of contractures but can be used to relax broad areas under tension even utilizing scar tissue. The Z-plasty is indicated in the repair of finger webs, longitudinal scars of fingers and palm, band scars of the axilla and anti-cubital region and the contracted margins of grafts. Incisions crossing perpendicular to lines of tension will contract more than incisions parallel to



FIG. 13.—A direct abdominal flap applied to a large defect of the elbow.

tension lines. The Z-plasty prevents contracture in an incision crossing the lines of tension by substituting incisions which are oblique or parallel to the lines of tension. Longer scars may require multiple Z's. The Z-plasty is

FIG. 14-A

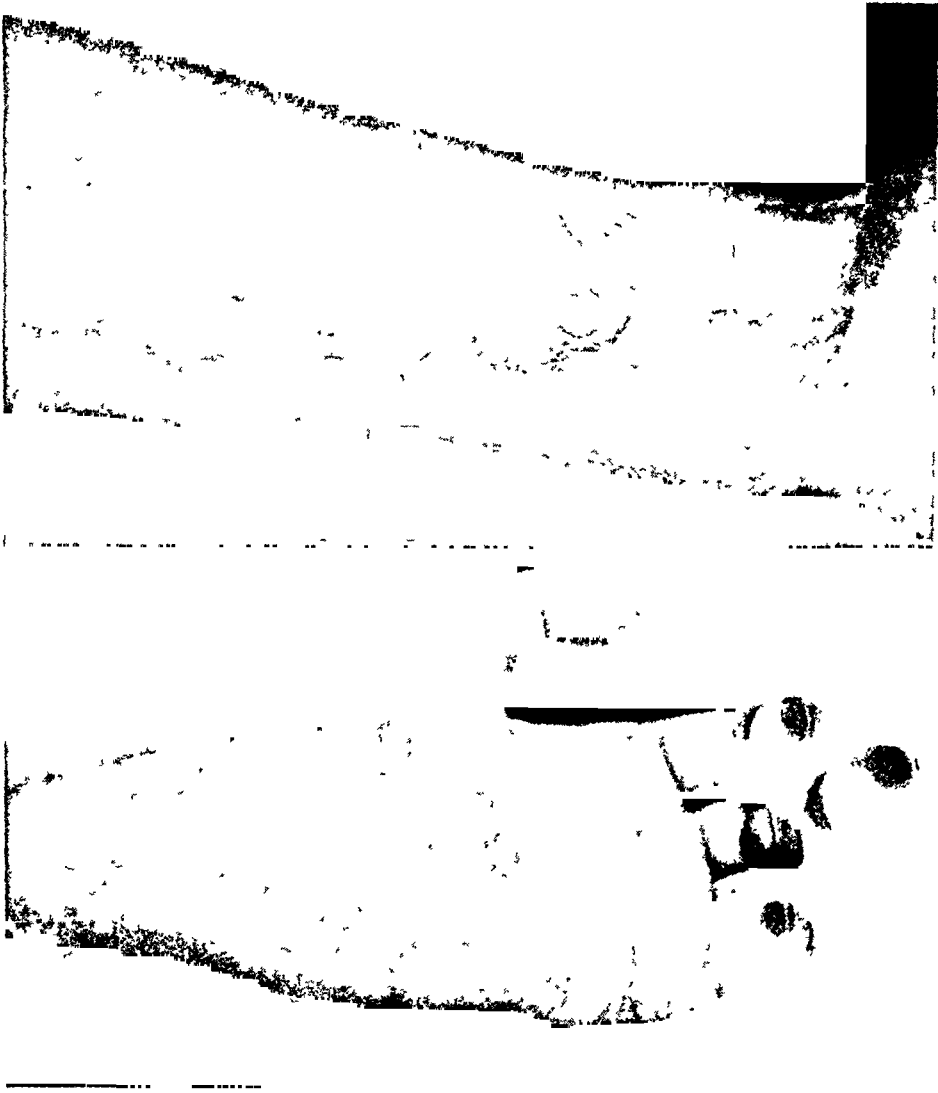


FIG. 14-B

FIG. 14.—(A) Adherent cicatrix of wrist with extensive loss of flexor tendons and median and ulnar nerves. The nerves were stretched as far distally as possible at the time of application of the flap.

(B) Result following application and division of flap.

mainly useful for release of surface contractures and does not usually supply a satisfactory bed for bone and tendon work.

Free skin grafts are indicated for surface replacements where local tissue is not available and where subcutaneous tissue does not need to be replaced. They are the method of choice for large superficial losses of skin, for instance burns and avulsed wounds. Thick-split grafts and full-thickness grafts are

better than thin-split grafts or small deep grafts because of less contracture. Full-thickness grafts contract very little and are movable over the underlying tissue shortly after the dressing is removed because of the presence of the deep

FIG. 15-A



FIG. 15-B

FIG. 15.—(A) Abdominal flap applied to antecubital region to correct severe flexion contracture involving biceps and including joint capsule. Extension was obtained at the time of application of the flap.

(B) Complete flexion is possible.

dermal layer which is normally mobile due to the loose arrangement of the fibrous meshwork and the presence of some fat and areolar tissue.

Thin grafts take more readily than thick grafts. Thin full-thickness grafts may be obtained for use on the hand from the lower abdomen, medial surface of the arm and anterior medial thigh. Thick-split grafts taken from these same areas, where the skin is thin, have much the same character as full-

thickness grafts and may largely replace them. Split grafts of the same thickness taken where the skin is thick, as on the back, split the derma where it is dense and less mobile and a graft with less pliability and more contracture results. Thus, the term "thick-split graft" is less descriptive of the functional result to be obtained than the term "three-quarter-thickness graft," as used

by Padgett. On a mobile base the pliability of the three-quarter-thickness skin graft, after several months, is equal to the full-thickness graft. The full-thickness graft is most useful on the palm and fingers.

Since the advent of the Padgett-Hood dermatome, excellent results have been obtained generally in resurfacing burned hands. Hypertrophic scars, or keloids, with contracture and a tendency to ulcerate are best completely replaced by a single large sheet of thick-split skin. If more than one graft is used the line of junction should be zig-zagged or placed to prevent contracture. The margins of the graft should be treated similarly, incising into, or even sacrificing, some normal tissue. The margins on a finger should



FIG. 16.—Direct abdominal flap applied to the dorsum of the hand. Arthroplasty was done at the time of application. Fingers are in traction following extensor tendon graft.

extend to the midlateral region. Better healing of the margin is obtained if the edge of the graft is sutured to the skin edge rather than overlapped. A good "take" is obtained by perfect hemostasis, adequate immobilization and pressure dressings. Massive fluffed-gauze dressings distribute pressure evenly and prevent pressure points. Small grafts are usually immobilized by tying interrupted sutures over a stent of gauze. Extensive deep repair is not usually possible under a free graft unless there is adequate soft-tissue underlying the graft to maintain the blood supply.

Stiffened metacarpophalangeal joints with subluxation and extension deformity are often found in severe burns of the hand. In severe or long standing cases they may not be corrected by manipulation at the time of grafting. Traction will not be effective before grafting because of the contracted scar and excess skin cannot be applied at the time of grafting unless the deformity is corrected. We have handled this problem by combining, as one procedure, capsulotomy, after the technic of Bunnell, with free skin grafting. Excision of the lateral ligaments does not always allow the joints to flex completely and manipulation to slide the proximal end of the phalanx over the metacarpal head is required. In some few cases even this maneuver must be supplemented by surgically releasing the contracted or adherent anterior capsule.

## SURFACE DEFECTS OF UPPER EXTREMITY



FIG. 17.—(A) Defect of forearm with loss of distal ulna, and one-half the shaft of the radius, with osteomyelitis. The sinus was opened, sequestra removed and the wound saucerized. A split-thickness skin graft was applied at the time.

FIG. 17-D

(B) Skin graft has been removed and abdominal flap applied. (C) The donor area and base of the flap, showing closure by split-skin graft. (D) Final appearance of flap.

FIG. 18-A



FIG. 18-B

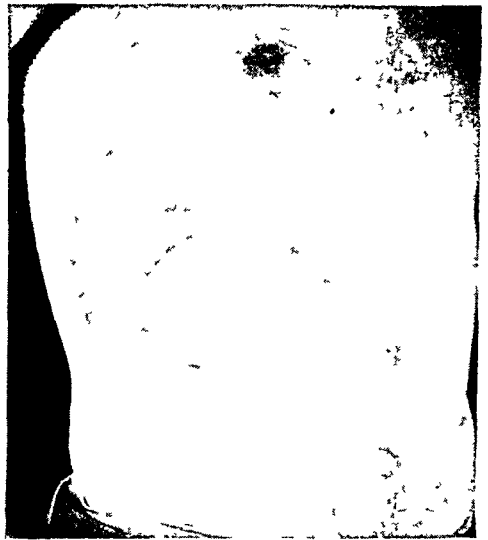


FIG. 18-C

FIG. 18.—(A) Large direct abdominal flap applied to the forearm from above the elbow to the wrist.  
 (B) Healed donor area on the lower chest and abdomen which was grafted when the flap was applied.  
 (C) Appearance of the flap following division.



FIG. 19-A

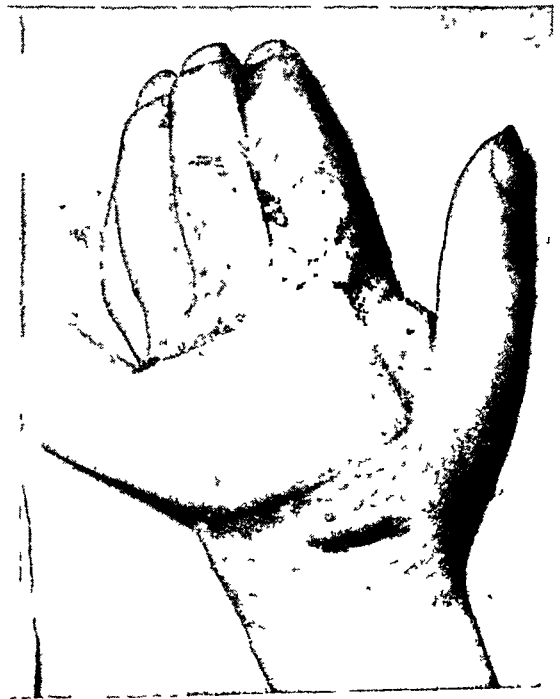


FIG. 19-B

FIG. 19.—(A) Open wound of dorsum of hand with loss of extensor tendons and fracture of metacarpals.  
 (B) Wound closed by direct abdominal flap with donor area closed by suture. The base of the flap was grafted.

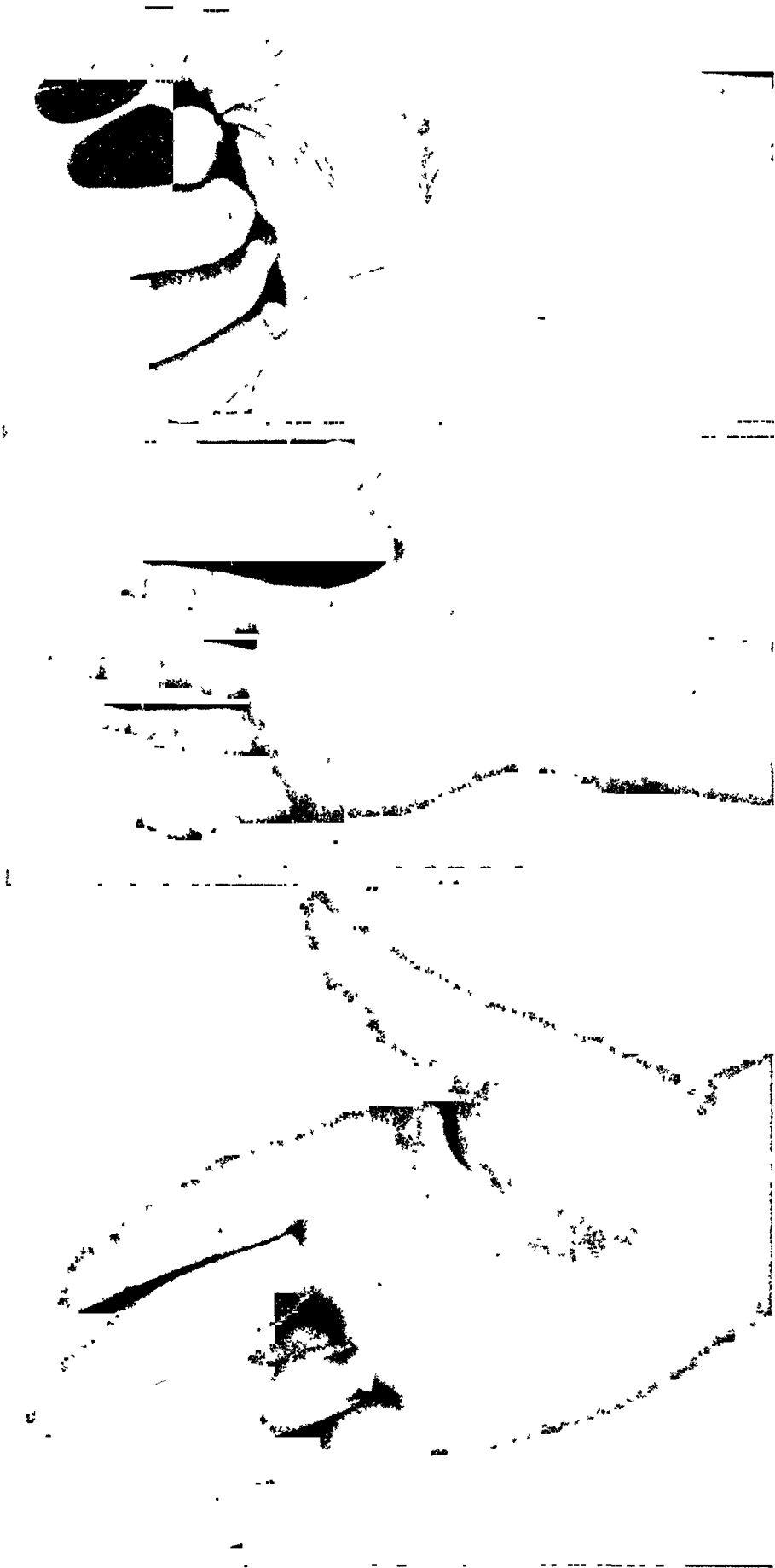


FIG. 20-A

FIG. 20-B

FIG. 20-C

FIG. 20.—(A) Severe flexion contracture of the ring finger with loss of distal profundus tendon and fixation of the joints in flexion.  
(B) Contracture corrected by a direct abdominal flap and capsulotomy of interphalangeal joints.  
(C) Flexion was obtained by resuture of profundus tendon to distal phalanx.



Recently avulsed skin with insufficient blood supply to use as a flap can be replaced if it is trimmed down to a full-thickness graft, after the method of Farmer, or it may be glued to the dermatome and the skin split from the subcutaneous tissue at any desired level.

Pedicle grafts make possible the application of both skin and subcutaneous tissue to surface defects. They are classified into two main types—flaps and tubes. They serve to provide padding, improve contour, increase circulation to a part and to cover avascular areas where tendon, bone or open



FIG. 21-A



FIG. 21-B

FIG. 21.—(A) Recently avulsed wound of the thumb with exposed tip of the distal phalanx, a few days following injury.

(B) Final result after application of a direct abdominal flap. The nail and length of thumb were preserved.

joints are exposed. They provide tissue under and through which operative work on movable parts may be done. They may be used for closing deep open wounds instead of free grafts, thereby providing the final tissue covering. While free grafts may not be applied to a poorly nourished bed, for instance roentgen-ray burns, the pedicle may be used if the edges of the pedicle are attached to normal surrounding tissue. The margin of any pedicle should always be applied to tissue of normal vascularity and the pedicle should not be laid on a bed of dense scar tissue as it will develop circulation poorly and the attached surface will tend to contract, causing it to become firm, edematous and rounded.

Rarely, a pedicle can be utilized mainly to provide subcutaneous tissue

# PLATE I

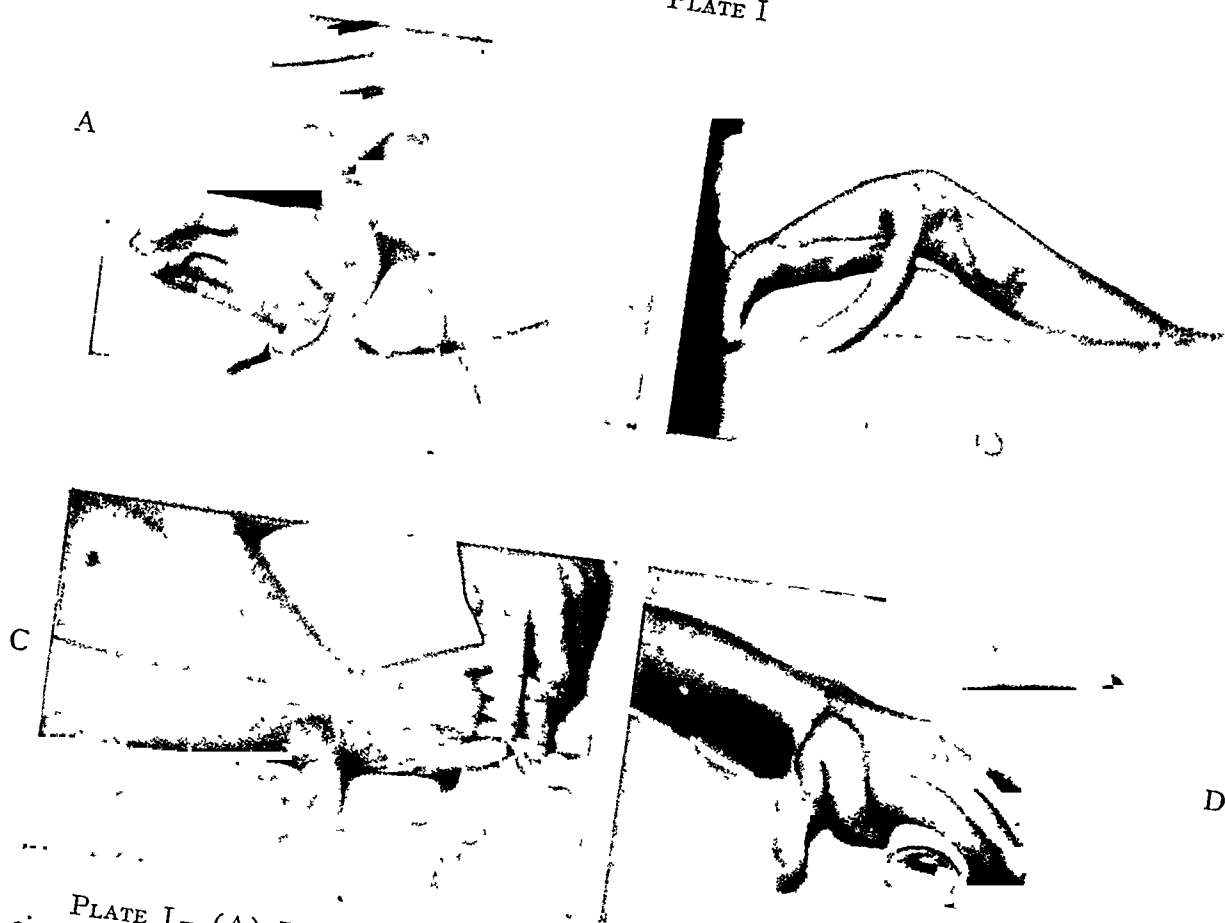


PLATE I.—(A) Double pedicle abdominal tube applied following excision of severe cicatrix of palm with extensive loss of thenar muscles, flexor tendons and nerves. The tube was applied to the wrist when divided.

(B) Application of a double pedicle tube to a severe injury of the hand and forearm.

(C) One-stage single pedicle abdominal tube applied to the wrist. At the time of application the ends of the divided median and ulnar nerves were overlapped by suture. At the time of division the nerves were sutured.

(D) One-stage single pedicle abdominal tube applied to web space to relieve contracture between the thumb and index finger. At the time of division the tube may be easily draped into the palm if required





FIG. 22-A

FIG. 22-B

FIG. 22.—(A) Shotgun injury with loss of index finger and injury of all flexor tendons in middle, ring and little fingers. (B) Direct abdominal flap has been applied to the base of palm and fingers. At the time of revision of the flap, ten No. 6 shot were removed from the profundus tendons, the sublimus tendons were removed and fatty areolar tissue was wrapped around the profundus tendons. Photograph shows almost complete flexion which was present ten weeks following operation.

FIG. 23-A

FIG. 23-B

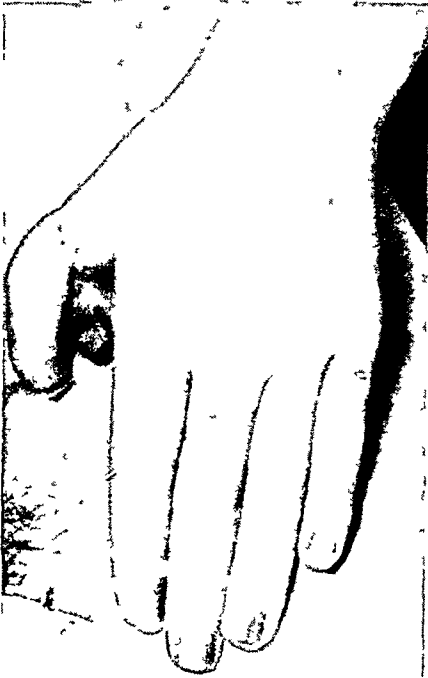
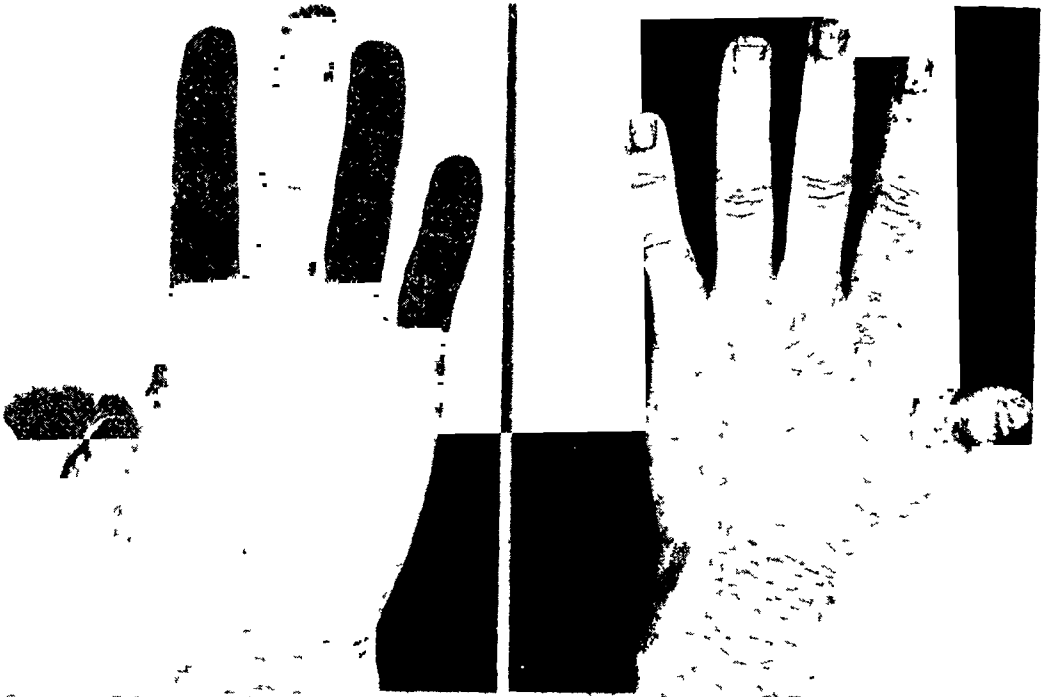


FIG. 23-C



FIG. 23-D



FIG. 23-E

FIG. 23.—(A and B) Deformity of thumb with loss of proximal phalanx. Sensation was present in the tip because of one remaining digital nerve.

(C) One-stage single pedicle abdominal tube applied after two-thirds of the attachment to the tip had been divided.

(D) Lengthening of thumb obtained by draping the tube completely around the thumb following division. One artery and the nerve were preserved. Sensation was retained.

(E) Early result following bone graft from metacarpal to distal phalanx.

FIG. 24-A



FIG. 24-B

FIG. 24.—(A) Extensive defect of hand with amputation of middle, ring and little fingers and marked ulnar deviation of index finger secondary to cicatricial contracture and fracture of metacarpal.

(B) Double pedicle tube has been applied and ulnar deviation of index finger corrected by excision of scar tissue

and little or none of the skin used. In one instance of this kind subcutaneous tissue was placed beneath normal palmar skin to provide a bed for tendon graft and nerve suture.

The best donor site for flaps and tubes to be applied to the upper extremity is found on the abdomen or lower anterior thorax. Thin or thicker skin may be obtained with or without hair, and the donor defect may be closed or grafted with little deformity and no disability. Very large pedicles may be obtained and an excellent blood supply is assured if the arrangement of the



FIG. 25-A

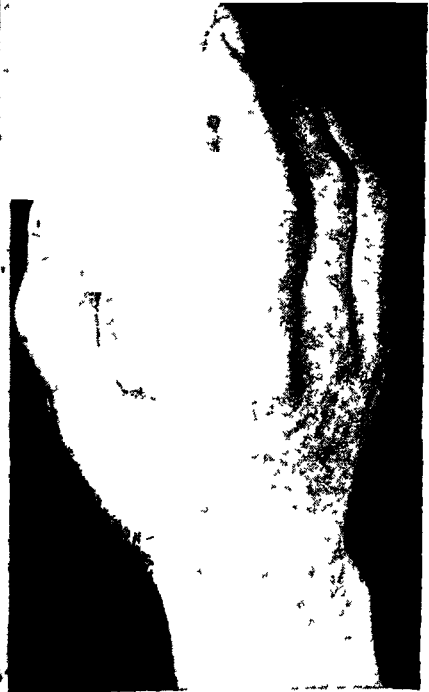


FIG. 25-B

FIG. 25.—(A) Wound of thumb secondary to an electrical burn. The flexor pollicis longus tendon was lost. The proximal phalanx and the metacarpophalangeal joint were exposed.

(B) Wound was closed by application of direct abdominal flap. Joint motion was preserved in the metacarpophalangeal joint. A flexor tendon graft was done at the time the flap was revised.

vessels is kept in mind. This large area is accessible to the upper extremity, and combined with the adaptability of the hand to various positions a wide choice of location and direction of pedicle is provided. There is no indication for using the back or the buttocks as a donor area. The skin is thick, the position is unnatural and the scar may be painful. Cross-arm flaps have been used in a few cases but the procedure has been discarded because the type of skin does not compensate for the scar or the immobilization of both arms. Although the skin is thin and pliable it is little better than that found on the lower lateral abdomen.

Direct abdominal flaps are so-called because they are raised and applied

directly to the recipient area. They may be open or closed, depending on whether or not the donor area or the base of the flap is left to granulate until the time of division. They offer a simple, quick method of replacement and usually are easily applied. Nearly every size or shape of defect found on the

FIG. 26-A

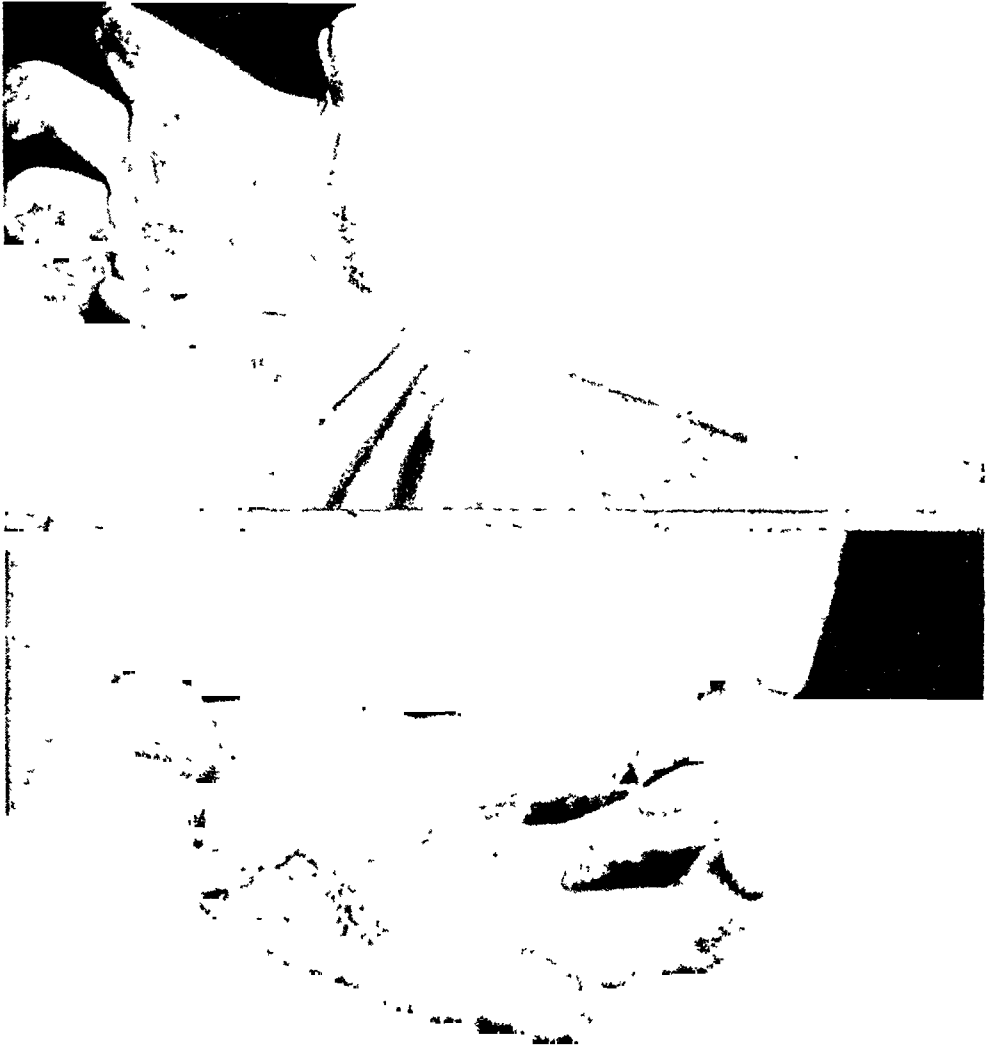


FIG. 26-B

FIG. 26.—(A) Severe wound of hand with flexion contracture of ring and little fingers and painful amputation stumps of thumb, index and middle fingers.

(B) The flexion contractures of the ring and little fingers, the web between the two and the cicatrix in the palm have been corrected by multiple Z-plasties and thick split-skin grafts. The amputation stumps of the thumb, index and middle fingers have been revised. The normal web between the thumb and index finger has been deepened by a Z-plasty to improve the grasp.

hand or forearm can be covered with reasonable care and planning. Two flaps may be applied to two different areas at the same time or a paddle may be delayed on the applied flap to be draped into position when it is detached.



In general, vertical flaps have a better blood supply because of the primarily vertical pattern of the superficial vessels between the groin and axilla. Only under extraordinary circumstances is it necessary to delay an abdominal flap prior to application.

Closure of the donor defect of the flap may be accomplished by split-skin grafting or suture following undermining. If it is grafted, the base of the flap may also be closed by extending the graft to the edge of the defect on the extremity. Where the donor area is closed by suture the base of the flap may be closed by grafting. Better healing of donor sites is usually obtained by suture than by grafting and the abdominal scar is more satisfactory. Quite large defects may be sutured.

In applications to the hand the wound of the open flap, even if kept surgically clean, leads to edema, stiffening of joints and pain. In our opinion, this constitutes an unhealed wound of the hand which delays or impairs return of function. Many flaps are applied to clean healed hands. It seems inexcusable to convert a healed area into an open wound when it can so easily be avoided. Relatively short additional time spent at the first operation saves dressing time and preserves the principle of keeping surgical incisions closed. In addition, the patient is more comfortable with a closed, cleaner wound which permits greater freedom of activity.

Double pedicle or pocket flaps are not necessary or desirable. The donor site cannot be closed as is often possible with a single pedicle flap and a clean well-healed graft is difficult to obtain. There is a more extensive wound to be closed at the time of division.

The usual double pedicle tubed-graft is mainly useful in cleanly carrying tissue to a distance. Because of the time required and hospitalization involved, it is not often indicated for the forearm and hand unless the defect is long and the direct flap is not easily applied. However, a well-healed pedicle does allow more flexibility and the application may be made under circumstances in which a direct flap would be most difficult, as for instance where there is limited pronation and supination in the forearm and lack of motion in the elbow. Sometimes it is desirable to establish a tube on the extremity for application at the time of subsequent surgery—for instance in relieving severe joint contractures and at the same time doing extensive surface replacement. The authors have favored vertical or slightly oblique tubes including the thoraco-epigastric vein, after the method of Webster. This is because the best blood supply is utilized in this manner and very large donor defects may be closed.

Paddles are seldom constructed on the ends of tubes because they usually require one or two additional operations for delay. Whenever possible the tube is originally planned to provide for the entire defect without a paddle.

One-stage single pedicle tubes have recently been described by the authors. They are usually based inferiorly to include the superficial circumflex iliac or superficial epigastric veins. They combine the cleanliness and mobility of the tube with the speed of the direct abdominal flap. They have been found quite useful and adaptable for the repair of defects on the hand and wrist.

At the time of application of a flap or tube injured deep structures are often exposed in conjunction with the removal of scar tissue and the opportunity is presented to complete certain repairs or to prepare the field for subsequent surgery. Certain definite limitations are imposed on the extent of this repair by position and immobilization, and it is not advisable to superimpose an involved reconstructive operation on an extensive surface replacement. However, nerves may be sutured or the ends approximated as much as possible to facilitate later suture. Fatty areolar tissue may be wrapped around adherent tendons either utilizing the fascia of the flap or free grafts. Surgical mobilization of joints by removal of scar, capsulotomy or arthroplasty may be done and sometimes is required before the potential defect is available for the reception of the flap. Removal or division of extensively scarred and adherent tendons which are limiting motion of joints or producing contractures is especially indicated.

A common problem presented in the war casualties which we have seen has been contracture between the first and second metacarpals, limiting the function of the thumb by preventing abduction and opposition. These injuries have combined loss of skin, deep scar, contracture of muscle and limited mobility of the first metacarpal on the greater multangular. Correction of the deformity requires excision of all deep scar tissue, section of the muscle sheaths, division of the insertion of the abductor pollicis tendon and division of the origin of the dorsal interosseous on the first metacarpal. In some instances it is necessary to incise the capsule of the first carpometacarpal joint. The relatively deep defect is covered by a pedicle flap. The one-stage single pedicle abdominal tube has been especially valuable for this replacement.

#### SUMMARY

Indications for different types of surface replacement and their use on the upper extremity have been discussed, with special reference to particular problems of the severely injured hand.

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# EXPERIENCES WITH EARLY NERVE SURGERY IN PERIPHERAL NERVE INJURIES\*

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AND

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IN WORLD WAR I approximately 3,500 peripheral nerve injuries were sustained by U. S. Army troops, of which approximately 1,000 seem to have been treated by neurorrhaphy.<sup>1</sup> The results of this surgical effort, due to lack of an adequately planned and organized program for the study of neural regeneration, were for the most part lost. There do exist, however, sufficient statistical data, based upon individual surgical experiences, to justify the conclusion that the surgery of peripheral nerve injuries in that war was productive of disappointing results.<sup>1, 2</sup>

Under this stigma the surgery of peripheral nerve injuries was undertaken in World War II, and until the early spring of 1944 no coördinated program was established for their management. At this time two considerations stimulated the initiation of a gigantic clinical experiment in the early surgery of such injuries: (1) The certain expectation of large numbers of casualties; and (2) the demonstration that delayed wound closure, when employed as a fundamental surgical principle, was almost certain to prevent and control wound infection.<sup>3</sup>

A description of this program, a discussion of the neuropathologic principles upon which it was based, and certain interim and preliminary results which have flowed from it will be presented in this sequence. An attempt will also be made to correlate the lessons learned from this mass of material with the immediate and relevant problems of civilian traumatic neurosurgery.

Before proceeding to the presentation of this material, certain facts concerning the neurosurgery of World War I should be briefly outlined.<sup>1</sup> Most of the patients with peripheral nerve injuries sustained in that war were treated in specialized centers in the Zone of the Interior. Although the advantages of early operation were fully appreciated, definitive surgery was not as a rule performed until several months after the wounds had been sustained. For this postponement there were two reasons. The first was delay in evacuation, which was naturally very much slower in World War I than in World War II. The second, and even more important reason was the prevalence of wound infection. Platt,<sup>2</sup> in his excellent review of the remote results of nerve operations in World War I, pointed out that the vast majority of nerve injuries belonged in the "primary" class, being characterized by gross destruction, with immediate loss of anatomic continuity, but that wound infection was a potent secondary factor. "The fully-matured lesion as seen during an exploratory operation,"

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\* Read before the Fifty-seventh Annual Session of the Southern Surgical Association, December 4-7, 1945, Hot Springs, Virginia.

he stated, "represents a composite histologic picture, to which the primary injury, the effects of wound infection, and the attempts at spontaneous repair on the part of the nerve have all contributed."

In the same review Platt cites Frazier's views as typical of prevalent American opinion concerning the appropriate time for operation in peripheral nerve injuries. In general, it was the practice to defer operation until at least three months after the wound had healed. Since, however, regeneration had been known to occur spontaneously as late as six months after the injury, and in rare cases after an even longer period, Frazier believed it wise to defer operation until this time. Then, if there were no evidence of regeneration, or if regeneration had begun but had not progressed, or if neuritis were evident, operation was regarded as indicated.

The statistics presently available for World War II show that approximately 25,000 patients with peripheral nerve injuries, representing some 10.5 per cent of all battle casualties, reached the level of the General Hospital. Though the figures are necessarily incomplete at this time, to date 7,000 cases of end-to-end suture have been recorded in the Peripheral Nerve Registry, which was established in November, 1944, for the purpose of assessing the progress of these cases at regular intervals.<sup>4</sup>

The statistics which have just been cited show the magnitude of the problem of peripheral nerve surgery in World War II. The task of evaluating the end-results of therapy, that is, neural regeneration, is a problem equally pressing and important, but is not one which can be concluded within a short time. Five years, at least, must elapse before definitive statements can be made concerning many of the results of the management of peripheral nerve surgery in World War II, but the material already in hand is sufficiently comprehensive to warrant certain preliminary statements concerning the end-results to date.

#### THE PROGRAM FOR THE MANAGEMENT OF PERIPHERAL NERVE INJURIES

It is an axiom of military surgery in an Overseas Theater that elective procedures should be kept at a minimum, so that a pool of hospital beds will always be reserved for unpredictable emergency use. Since the repair of peripheral nerves is chiefly elective, and since casualties with major nerve injuries are for the most part never again fit for combat duty, it is apparent, from the military standpoint, that such patients should be evacuated to permanent hospital installations at the earliest possible moment. From the surgical standpoint, after measures have been taken to preserve the extremity and to prevent infection, the patients' own best interests also demand that they should be promptly transferred to installations in which elective nerve surgery can be done.

Uncomplicated peripheral nerve injuries do not merit a high evacuation priority, and for this and other reasons, a large number of patients with nerve injuries sustained in the North African campaign did not reach Neurosurgical centers until six months, or more, after they had been injured. Before the start of the European campaign a provisional program was formulated for the treatment of peripheral nerve injuries in Neurosurgical Centers established in

the United Kingdom. Details of the program became more definite as experience increased with the increasing flow of battle casualties. It was still necessary, however, for patients with such injuries to accept a relatively low evacuation priority, the highest priorities in the neurosurgical category being given to brain and spinal cord injuries. It soon became evident that even under optimum conditions of *triage* patients with peripheral nerve injuries were reaching the Neurosurgical Centers in the United Kingdom no earlier than 14 to 21 days after wounding, having in the interim passed through two or more General Hospitals which were serving as transit installations. Many of the patients, in spite of the retarded evacuation, arrived with soft-tissue wounds still unclosed, and the first concerted effort in the new program was to expedite early wound closure, so that nerve explorations, with neurorrhaphy if necessary, could be instituted promptly upon their arrival at the Neurosurgical Centers. This was accomplished by directives, circular letters, conferences, personal contacts, and similar means.

Soon after the institution of the program it became apparent that peripheral nerve injuries repaired three to four weeks after wounding and delayed wound closure presented fewer technical problems than when nerve suture was delayed for a period of months. Mobilization of the proximal and distal nerve segments was more readily accomplished at this time because wound fibrosis was minimal, the pathologic changes at the point of nerve severance were usually not extensive, and when joint flexion was necessary, this method of decreasing the nerve gap was not prejudiced by static joint fixation. The soundness of the plan of early nerve surgery is evident from two very striking facts,<sup>5</sup> that the incidence of insurmountable nerve gaps in the cases operated upon by this plan was less than 1 per cent, and that primary wound healing, in marked variance to the World War I experience, occurred in over 98 per cent of the cases subjected to definitive nerve surgery.

The selection of cases for the performance of early nerve surgery overseas was dictated by a number of considerations, the chief of which, as already pointed out, was the administrative task of evacuation, based upon military exigencies. Patients with extensive soft-tissue wounds requiring plastic surgical procedures and those with severe associated lesions of other types were prepared for further evacuation without definitive nerve surgery. Those with severe infections of the long bones, for instance, were evacuated without delay. When evacuation of uncomplicated nerve injuries to the Zone of the Interior was delayed because of lack of facilities for evacuation, the waiting period was utilized for reparative nerve surgery; in no instance, however, was operation permitted to retard evacuation. To expedite this policy disposition board proceedings were completed as soon as the patients were admitted to the hospital.

Every surgeon who participated in the peripheral nerve suture program was instructed in the generally accepted principles of operative treatment and in the regimen of postoperative care. Particular stress was placed upon the following essential considerations:

1. The suture line must be free from tension, this result being accomplished by extensive dissection, with transplantation of the proximal and distal nerve segments if indicated, rather than by excessive or unphysiologic flexion of contiguous joints.

2. The proximal and distal nerve ends must be accurately trimmed until grossly normal nerve ends were visible.

3. The transected nerve ends must be approximated by a very carefully performed interrupted epineural suture. The use of a transneural or sling suture was left optimal with the surgeon.

4. Rigid hemostasis was mandatory and was to be accomplished without the use of a tourniquet unless required by an associated vascular injury.

5. Nerve lesions other than division were to be treated by strict conservatism.

Tantalum wire, 0.003-inch, swedged upon atraumatic needles, was recommended but not made mandatory; fine silk could be used if it were preferred. The wire suture material, however, was considered superior to other materials for a number of reasons. Experimental studies had shown it to be inert in human tissue, and even at the beginning of the program it was surmised that potential suture line disruption could be recognized early by roentgenologic studies of a radiopaque suture line. When the necessity of later evaluation of large numbers of patients submitted to nerve suture is borne in mind, the importance of this consideration is manifest. Preliminary surveys of the patients reported in this paper, as well as those operated upon in Centers in the Zone of the Interior,<sup>4, 6</sup> have supported the validity of this technical advance.

A small cuff of 0.00025-inch tantalum foil was placed about the suture site in almost all the cases handled in the European Theater of Operations, though in one Center a plasma clot sheath was used. This variation was permitted because experimental studies suggested that this method was valuable, and a comparison between various methods of suture-line sheathing thus became possible.

Postoperative extension of flexed joints was started at the end of the second week and was completed by the end of the fifth week. Early extremity extension was permitted chiefly because wound fibrosis was minimal at this period after the initial injury. The need for reduction of the hospital days, contingent upon a constant demand for rapid evacuation to hospitals in the Zone of the Interior, also influenced the regimen of early extension. Neuro-pathologic studies<sup>4</sup> have shown that suture line disruption sometimes occurs when this plan is practiced, but the incidence is no higher than is noted when nerve sutures are protected for longer periods of time.<sup>6</sup>

It was constantly emphasized to all the participants in the peripheral nerve surgery program that operation is but a single stage in the treatment of paralyzed extremities. In order to prevent temporarily denervated muscles from becoming irreparably atrophied and fibrosed, physical therapy, chiefly in the form of galvanic stimulation, was employed before and after operation. The clinical use of this special method of physical therapy was based upon well

documented experimental studies.<sup>7, 8</sup> When plaster encasements were used for postoperative immobilization, particularly in cases with associated injuries of the long bones, windows were cut over the bellies of the paralyzed muscle groups and galvanic stimulation was begun the day after operation. Other postoperative measures included massage, active and passive joint movements, and the use of dry and moist heat. Attention was repeatedly directed to maintenance of the mobility of the hand, which was achieved by minimal splinting and by detailed instructions to the patient in the care of his own disability.

At the start of the peripheral nerve surgery program, operation was attempted only in cases uncomplicated by associated or concomitant injuries. As experience increased, combined bone and nerve cases were carefully admitted to the same program, and some 300 patients were operated upon by this plan within an average time of 42 days after wounding.<sup>5</sup>

*Results.*<sup>5</sup>—Of 6,245 battle casualties with major nerve injuries treated in General Hospitals of the United Kingdom between D-Day and V-E Day, approximately 11 months, 2,873, or 46 per cent, were operated upon within the period designated as "early." The remaining patients, for reasons of military necessity and for other reasons, were evacuated to the Zone of the Interior. The time-lapse between wounding and operation varied from an average of 28 days in the weeks immediately after D-Day to 42 days in the period of heaviest fighting before V-E Day. The average of 39 days for the whole group was well within the optimum limits for repair, and, on the whole, probably represents the shortest practical time within which definitive nerve surgery can be done upon a large group of casualties under conditions of warfare. Nerve suture was performed in 54 per cent of the cases; in the remainder of the group, the nerve trunk was found in continuity and only neurolysis was done. The surgical mortality was 0.03 per cent, the single fatality presumably being the result of a procaine reaction.

The high percentage of normal healing (more than 98 per cent) is convincing testimony to the wisdom of delaying nerve surgery for three to four weeks after initial débridement of the wound. This excellent record was achieved solely by the practice of initial débridement, delayed wound closure, and the application of modern chemotherapeutic methods as prerequisite to definitive nerve exploration.

#### THE PATHOLOGIC BASIS FOR THE SELECTION OF THE TIME FOR DEFINITIVE NERVE SURGERY

In contrast to the progressive intraneural pathologic changes which dictate in large part the upper level of the optimum time for nerve repair, the factors which contraindicate primary nerve surgery in war injuries are entirely technical and mechanical: (1) The suture of a divided peripheral nerve at the time of wound débridement is not feasible by any technical standards, nor is it compatible with the surgical principles of preservation of life or extremity, or of the prevention of infection, which must be dominant at this time. (2) It is not possible for the surgeon at this time to estimate the intraneural damage to nerve segments adjacent to the point of severance caused by the distribution of



force developed by the war missile. (3) Selective section of nerve ends prior to suture is impossible unless a large nerve gap is arbitrarily established. (4) Mobilization and transplantation procedures essential for restoring the nerve gap and delimiting suture line tension are surgically unsound for fear of infection. (5) While in cleanly lacerated or in small penetrating wounds immediate nerve suture might be carried out by flexion of contiguous joints, the results in cases in which nerve gap has been overcome by flexion alone are likely to be prejudiced both by joint contractures and by the adverse effect of postoperative stretch upon the suture line.<sup>9</sup> Moreover, this method may not be applicable if the point of suture is distant from an articulating surface. (6) Finally, the epineurium of a freshly divided nerve is thin and friable, and lacks the tensile strength to hold sutures.

In spite of this array of arguments, surgical opinion is by no means unanimously in favor of delayed nerve suture. On the other hand, the case for this plan has been well stated by Seddon:<sup>9</sup> “. . . the delayed operation (in war wounds of peripheral nerves) converts the suture from a procedure carried out under restriction into one in which the surgeon is free to do as he wishes. At Oxford, all the primary sutures compare unfavorably with early secondary sutures, and if I had the misfortune to suffer a nerve injury myself I would prefer the secondary operation.” The results of this plan, as will be pointed out later, have fully justified its use.

The practice of delaying operation to wait for evidence of spontaneous regeneration is indefensible. In the interim irreversible pathologic changes occur in the form of progressive degenerative changes in the distal nerve trunk, nerve endings and distal articulations, which impair and eventually invalidate the functional results of axonal regeneration. Furthermore, there is considerable evidence that these alterations impair nerve regeneration adversely in direct ratio to the length of time between the injury and the attempt at definitive suture.

A description of the entire gamut of changes in all the tissues of a denervated extremity is too complex a task to undertake here, and the emphasis will be directed to the most important alteration, which occurs in the distal nerve segment.

The first evidence of changes leading eventually to deterioration of the distal nerve trunk throughout its entire extent is a slight fibrotic thickening of the epineurium, which occurs between 15 and 25 days after severance of the nerve. Within this period the epineurium first attains the tensile strength which facilitates nerve suture. As time passes, the distal trunk exhibits two types of tissue reaction. The first type may be summed up in a single word—fibrosis. The epineurium becomes thicker and more dense. Collagenous tissue spreads diffusely in the interfascicular spaces. The normal cross-section area of the fascicles is diminished as the result of an enveloping perineural fibrosis which may progress to practical obliteration of the fascicular masses. Although the entire cross-area of the distal nerve trunk diminishes in size, the atrophy of fascicles is compensated for by a relatively greater ratio of interfascicular

fibrosis. Simultaneously with the fibrotic changes described there may be seen an endoneurial fibrosis, which at times almost replaces the attenuated groups of atrophic tubules.

FIG. 1-A

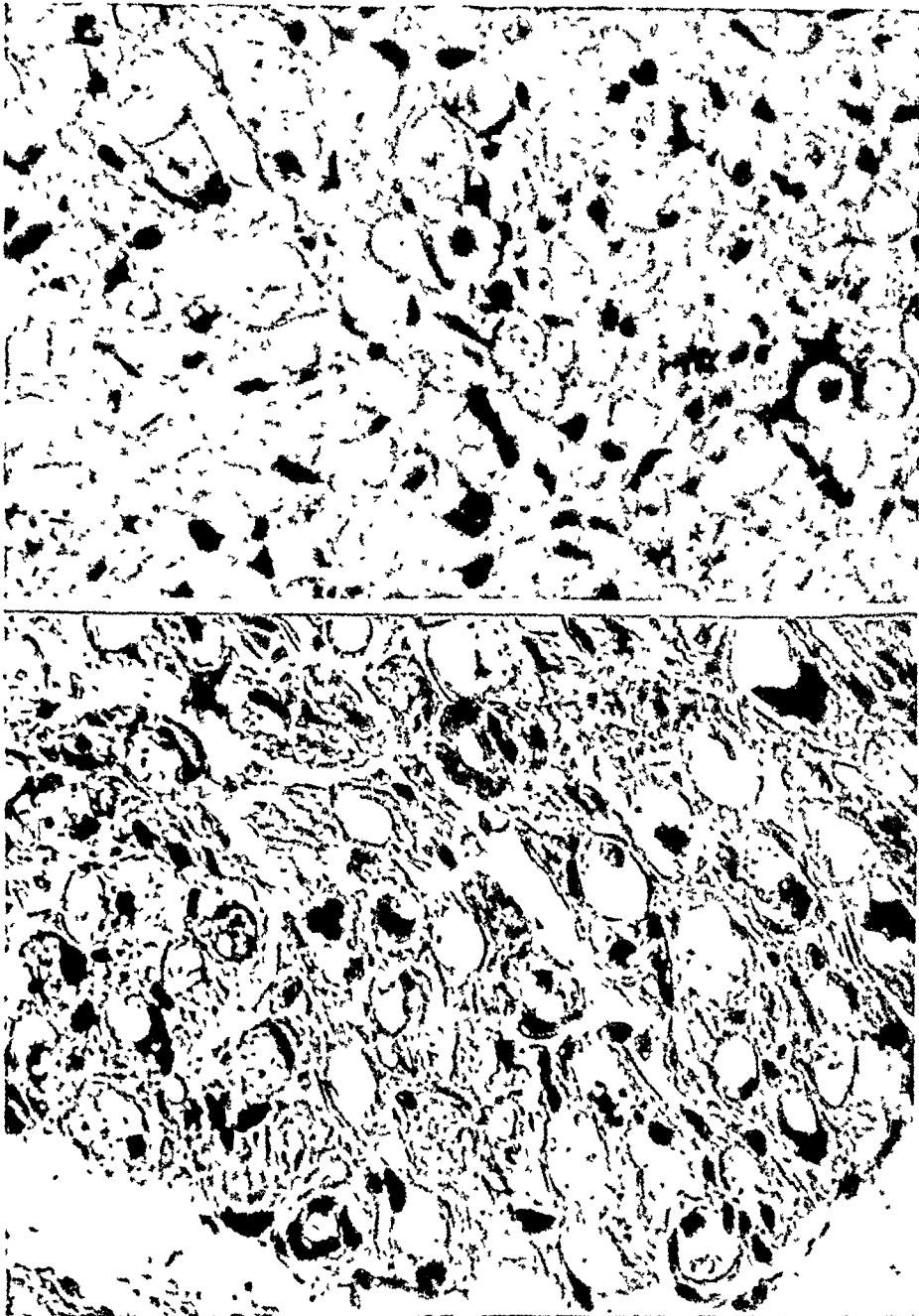


FIG. 1-B

FIG. 1.—(A) Cross-section of distal nerve segment, median nerve, seven days after nerve division, showing unshrunk tubules filled with degeneration products. (Protargol and aniline blue, x600.) (B) Cross-section of distal nerve segment, ulnar nerve, one month after nerve division, showing unshrunk tubules, digestion chambers and lipophages. (Protargol and aniline blue, x600.)

The second major change in the distal trunk, which takes the form of tubule atrophy, can with some qualifications be readily associated with the lapse of time after wounding, although it is difficult to correlate exactly the fibrotic

FIG. 2-A

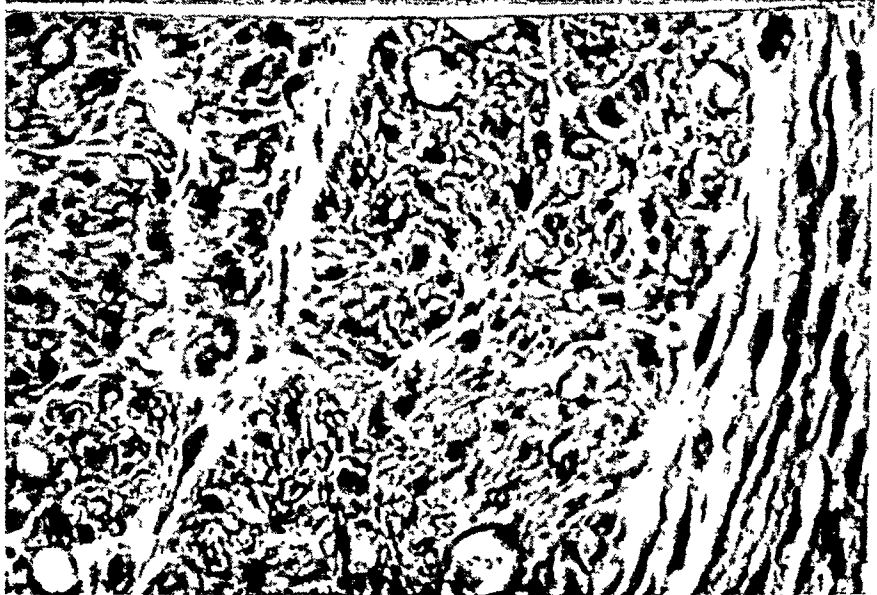
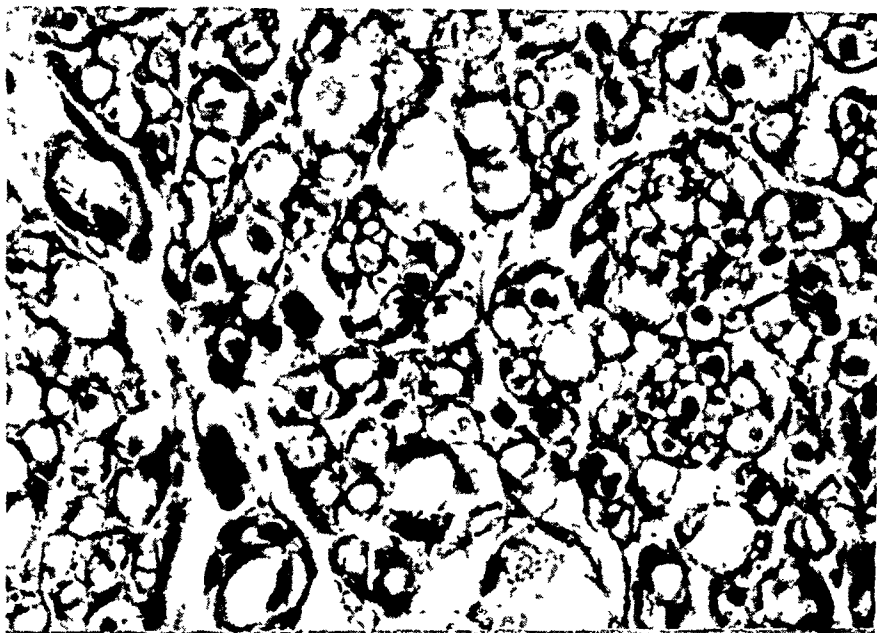


FIG. 2-B

FIG. 2.—(A) Cross-section of distal nerve segment, median nerve, two months after nerve division, showing unshrunk tubules with some variation in size. A few dots are seen against the circular neurolemmal sheaths, representing scattered regenerating fibers. (Protargol and aniline blue,  $\times 600$ .) (B) Cross-section of distal nerve segment, ulnar nerve, two and one-half months after complete neuroma in continuity. The majority of the tubules have become atrophic and are being replaced by an endoneurial fibrosis. The perineurium is thickened. (Protargol and aniline blue,  $\times 600$ .)

# PERIPHERAL NERVE INJURIES

FIG. 3-A



FIG. 3-B

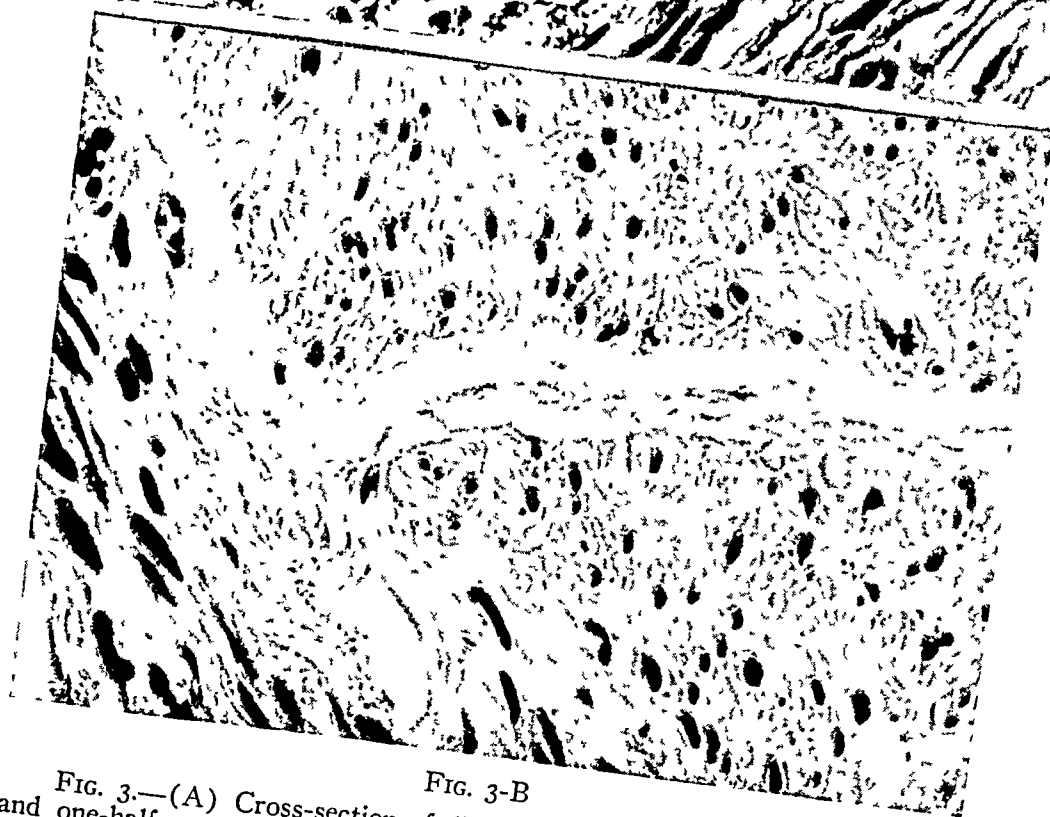


FIG. 3.—(A) Cross-section of distal nerve segment, sciatic nerve, four and one-half months after complete neuroma in continuity. Only a few tubules remain unshrunk and endoneurial fibrosis is present. A few regenerating fibers are visible as small black dots about the periphery of the tubules. (Protargol and aniline blue, x600.) (B) Cross-section of distal nerve segment, median nerve, five months after nerve division, showing advanced atrophy of tubules with marked endoneurial fibrosis. (Protargol and aniline blue, x600.)

FIG. 4-A

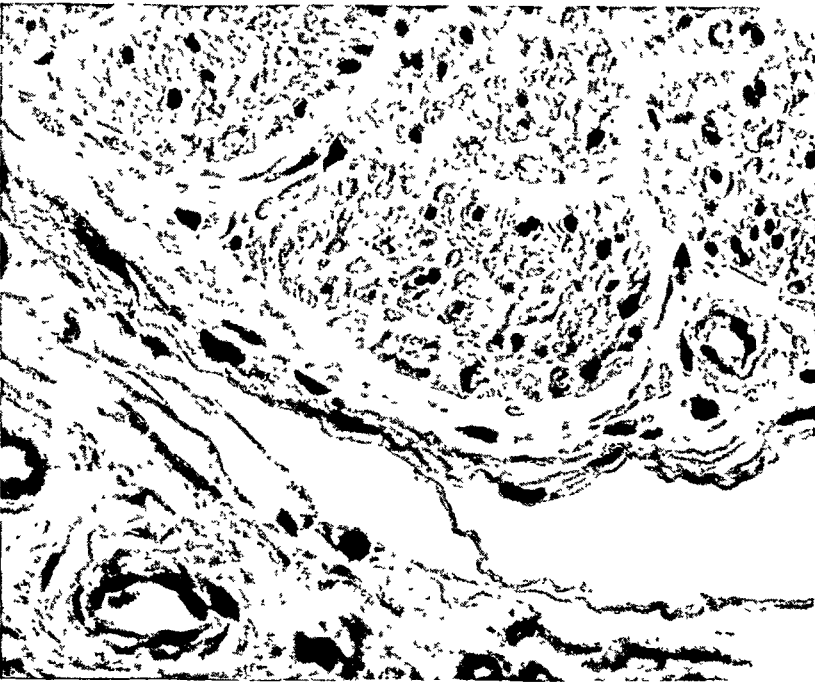
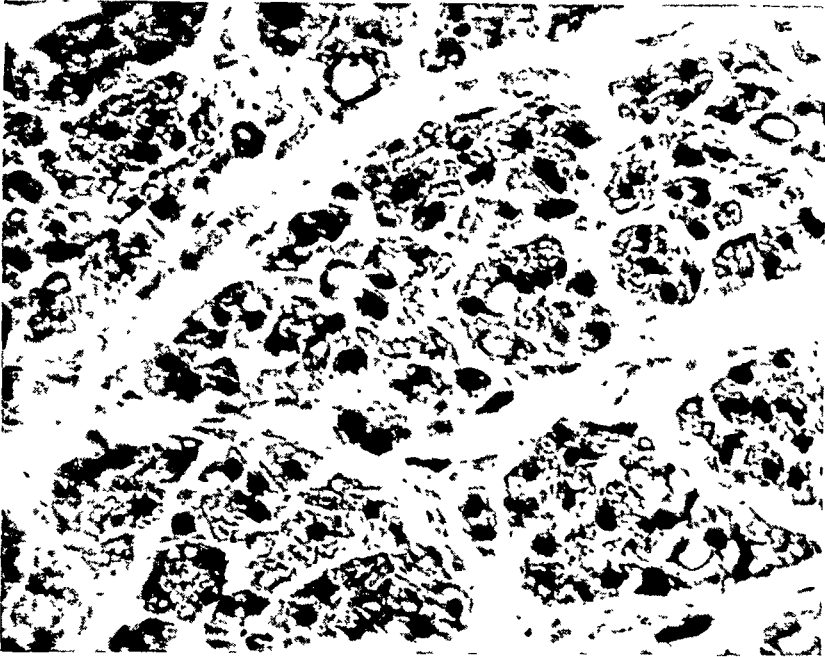


FIG. 4-B

FIG. 4.—(A) Cross-section of distal nerve segment, ulnar nerve, six and one-half months after nerve division, showing advanced tubular atrophy and endoneurial fibrosis. A few digestion chambers remain. (Protargol and aniline blue, x600.) (B) Cross-section of distal nerve segment, posterior tibial nerve, 14.5 months after nerve division, showing almost complete obliteration of the tubule lumina by a thick endoneurial fibrosis. There is some perivascular fibrosis. (Protargol and aniline blue, x600.)

changes first described with the passage of time. Progressive tubule atrophy in uncomplicated nerve injuries may vary in severity from case to case, but it remains a stable measure of the duration of distal segment deterioration unless it is even more adversely influenced by the factors of ischemia or traction. The normal maturation of regenerating nerve fibers depends to a large extent upon the number and volume of these tubular spaces. It will be noted in the groups of distal segment cross-sections, shown in Figures 1-4, that the tubule cross-section maintains its normal size until the end of the third month, after which rapid deterioration in size ensues. The volume of the tubular mass is replaced by a progressive endoneural fibrosis which (as shown in the 14.5-month specimen illustrated in Figure 4-A) may practically obliterate all evidence of tubule formation. Although the upper limit of potential functional regeneration cannot be fixed with certainty, it is a warrantable assumption, on the basis of this evidence, that it is within the three-month period following injury.

The pathologic basis for the selection of the optimum time for nerve repair can be determined with certainty only by comparison of nerve regeneration in a sufficient number of cases with the tissue changes present in individual cases. It is hoped that these data can be collected in the future through the Peripheral Nerve Registry and through the Peripheral Nerve Pathology Accession recently founded at the Army Medical Museum.

#### PRELIMINARY RESULTS OF EARLY NERVE SURGERY

A description of the Peripheral Nerve Registry, including the methods of recording essential data and of evaluating nerve regeneration, has previously been reported.<sup>4</sup> To recapitulate, at the time of definitive nerve operation, initiating forms are forwarded by the operating surgeon to the central repository. The form includes basic identification data and a summary of the operative procedure. At three-month periods thereafter an assessment form is compiled for each patient, recording relevant electrodiagnostic findings, the distal advance of Tinel's sign, and motor and sensory regeneration according to a simple code. During the interim stage the assessment form can indicate only a trend toward regeneration or failure of regeneration. On the other hand, these official records form the only practical method of collecting the fundamental data necessary for the future study of more complete neural regeneration in large numbers of cases.

For the purposes of the present study, samples of cases of early nerve suture, ranging in number from 450 to 649, were chosen for review as the records appeared successively in the Registry. Since each study was of a specialized character, the totals vary somewhat for each phase of the investigation.

*Causes of Failure.*—In one group of 602 cases, a study was made of the causes of failure of nerve suture which occurred in 44 cases, the neuropathologic study being conducted at the Halloran General Hospital.

Among 89 primary nerve sutures performed on the day of wounding, or shortly thereafter, as a part of wound débridement, there were 20 failures, or 22.4 per cent (Table I). This high proportion of failures when primary nerve suture was done is to be compared with the 21 failures (5 per cent) which

occurred in 419 instances of nerve suture completed after delayed wound closure.

Neuropathologic study of the 20 failures after primary nerve suture revealed the following data:

In one case an error in tissue identification had been made.

In one case suture of a partial nerve severance resulted in a neuroma in continuity.

In two cases, although the procedure was recorded as "suture," the divided nerve ends had merely been coapted with a single sling suture.

In 16 other primary sutures, a suture line neuroma had developed in 11 and suture line disruption had occurred in five. In these five cases a severe wound infection played an important rôle in the destruction of the suture line and also retarded the performance of secondary neurorrhaphy. Factors underlying the

TABLE I

DISTRIBUTION OF FAILURES IN 602 CASES OF PERIPHERAL NERVE INJURY ACCORDING TO HOSPITAL INSTALLATIONS:  
THE RELATION BETWEEN PRIMARY AND DELAYED NERVE SUTURE

Installation	Cases	Failures	Per Cent
Forward installations (primary suture).....	89	20	22.4
General hospitals (delayed suture).....	419	21	5.0
Installation unknown.....	94	3	
Total.....	602	44	7.3

development of suture line neuromas can only be surmised, but among them must be placed the inability of the surgeon to demarcate pathologic changes in freshly wounded nerve segments as well as postoperative tension on the suture line.

Neuropathologic study of the 21 failures of neural regeneration observed after delayed nerve suture revealed somewhat similar changes:

In one case an error in tissue identification had been made.

In one case regeneration was prevented by a circumferential wire sheathing-suture.

In one case the record did not make clear what procedure had been carried out at operation. A neuroma in continuity was found when late exploration was done.

In three cases nerve grafts had failed to take.

In five cases a suture site neuroma had developed.

In ten cases suture line disruption had occurred. In this group inadequate or accidental loss of postoperative immobilization seemed to play an important rôle.

*Evaluation of Regeneration.*—An analysis of 661 cases revealed that in 21.9 per cent definitive treatment had been carried out within 30 days after wounding, and in 73.9 per cent (the figures are cumulative), within 60 days; 91.8 per cent of all the cases were explored before the optimum time set for nerve repair had elapsed (Table II). The difference between these figures and those stated earlier for the individual survey of cases treated in Neurosurgical

Centers in the United Kingdom<sup>5</sup> is explained by the fact, that the Peripheral Nerve Registry covers cases of nerve suture from all Theaters of Operations.

In a group of 571 cases of early nerve suture, statistical sampling of assessments received at varying periods after operation disclosed a progressive

TABLE II

PROPORTIONATE DISTRIBUTION IN RESPECT TO TIME-INTERVAL BETWEEN WOUNDING AND DEFINITIVE NEUROSURGERY IN 661 CASES OF PERIPHERAL NERVE INJURY

Time-Interval (Days)	Actual Cases	Per Cent	Cumulative Cases	Per Cent
	63	9.5	63	9.5
6	22	3.3	85	12.8
12	13	2.0	98	14.8
18	16	2.4	114	17.2
24	31	4.7	145	21.9
30	37	5.6	182	27.5
36	66	10.0	248	37.5
42	74	11.2	322	48.7
48	68	10.3	390	59.0
54	50	7.6	440	66.6
60	48	7.3	488	73.9
66	26	3.9	514	77.8
72	21	3.2	535	81.0
78	34	5.1	569	86.1
84	26	3.9	595	90.0
90	12	1.8	607	91.8
120	33	5.0	640	96.8
150	10	1.5	650	98.3
180	1	0.2	651	98.5
Over 180	6	0.9	657	99.4
Unknown	4	0.6	661	100.0

TABLE III

TIME-INTERVAL BY MONTHLY ASSESSMENTS BETWEEN OPERATION AND FIRST APPEARANCE OF TINEL'S SIGN IN 571 CASES OF PERIPHERAL NERVE INJURY

Postoperative Time-Interval (Months)	Number of Total Assessments	Sign Present at Latest Assessment	Per Cent
1.9	57	38	66.0
2.9	73	53	72.0
3.9	157	133	84.0
4.9	83	61	73.0
5.9	47	39	83.0
6.9	68	59	86.0
7.9	25	21	84.0
8.9	22	19	89.0
9.9	21	20	90.0
10.9	3	3	100.0
11.9	3	3	100.0
12 and over	12	7	60.0

descent in Tinel's sign in a high proportion of patients (Table III). For example, in a group of 59 cases assessed 6.9 months after nerve suture, only nine failed to show this clinical phenomenon.

The trend toward motor and sensory regeneration was studied at various periods of time after nerve suture in 649 cases (Tables IV and V). Trends toward recovery in both respects improved progressively as time passed after



operation. For example, some evidence of motor regeneration was manifest in 33 of 166 cases assessed at 3.9 months after operation (approximately 20 per cent). In 28 cases assessed 8.9 months after suture, evidence of motor recovery was observed in 15 (approximately 54 per cent). Improving sensory status was observed in 32 of 165 cases assessed 3.9 months after operation (19.3 per cent). Similar improvement was observed in 17 of 27 cases assessed at 8.9 months after operation (63.3 per cent). Cumulative multiple assessment

TABLE IV

RATE OF SENSORY RECOVERY BASED ON MONTHLY POSTOPERATIVE ASSESSMENTS  
IN 649 CASES OF PERIPHERAL NERVE INJURY

Postoperative Time-interval (Months)	Monthly Assessments	Monthly Assessments with Recovery	Per Cent
1.9	63	8	13.0
2.9	74	10	14.0
3.9	166	33	20.0
4.9	90	20	22.0
5.9	55	16	30.0
6.9	81	48	59.0
7.9	32	14	44.0
8.9	28	15	59.0
9.9	37	19	51.0
10.9	6	5	63.0
11.9	5	5	100.0
12 and over	12	9	75.0

TABLE V

RATE OF MOTOR RECOVERY BASED ON MONTHLY POSTOPERATIVE ASSESSMENTS  
IN 649 CASES OF PERIPHERAL NERVE INJURY

Postoperative Time-interval (Months)	Monthly Assessments	Monthly Assessments with Recovery	Per Cent
1.9	61	7	11.0
2.9	76	9	12.0
3.9	165	32	19.0
4.9	91	20	22.0
5.9	56	24	43.0
6.9	80	48	60.0
7.9	32	18	59.0
8.9	27	17	63.0
9.9	36	27	75.0
10.0	6	6	100.0
11.9	5	5	100.0
12 and over	14	9	65.0

studies have not yet been completed in respect to either motor or sensory recovery.

In general, the statement can be made that the program of early nerve suture has demonstrated in the studies made to date a promising trend toward normal regeneration in most of the cases treated. The high incidence of failure in primary nerve suture has been clearly proved, and fully substantiates the directives issued during the war in the European Theater of Operations forbidding this procedure.

THE APPLICATION OF WARTIME EXPERIENCE TO CIVILIAN NEUROSURGERY

The question naturally arises at this time as to how the experience gained in the treatment of peripheral nerve injuries in wartime can be translated to civilian traumatic surgery. The wounding mechanisms in the two groups of cases are quite dissimilar. The disruptive, tearing force of a jagged fragment of metal with its pulsating cone of contiguous tissue destruction has no counterpart in the common civilian injuries in which cleanly lacerated wounds and closed injuries secondary to traction and to fracture or dislocation predominate.

The neurosurgical literature of World War I is replete with implications that although the treatment of peripheral nerve injuries was disappointing during the war, the treatment of civilian injuries of this type promised better results since infection would not play a rôle in the latter group. Infection played no rôle in the management of peripheral nerve injuries in World War II, and comparison with civilian injuries is, therefore, valid in this respect. Even with the factor of infection out of the picture, however, in civilian surgery neuro-pathologic studies suggest that the upper limit of the optimum time for nerve repair is in the neighborhood of three months following injury. Unless the course of expected spontaneous regeneration is checked, with due regard to the wounding mechanism, the rate of axonal regrowth, and the reinnervation of the proximal musculature, a policy of prolonged observation is never justified. This is particularly true when the wounding mechanism implies the possibility of complete nerve severance. In such a case as a simple fracture of the humerus with radial nerve paralysis, the minor procedure of early nerve exploration under local anesthesia is vastly preferable to delay that may impair the chance for full functional return.

The term "full functional return" must of course be used with qualifications based upon the association of extensive tissue or vascular damage, as well as with consideration of the specific function of the individual nerve. An analysis of the results of early nerve suture under the program used in the European Theater of Operations indicates that if a divided nerve is carefully repaired, if the wound is free from infection, and if the operation is done at the optimum time, early and progressive evidence of neural regeneration may be expected in contrast to the results of late nerve suture as practiced in World War I.<sup>1</sup>

Analysis of the cases recorded in the Peripheral Nerve Registry<sup>4</sup> indicates that a substantial percentage of unfavorable results follows primary nerve suture in war wounds. There is no factor present in the typical civilian type of nerve division, such as severance of the median nerve at the wrist, which would preclude the sequence of débridement, with or without delayed wound closure, followed by nerve suture *after* the initial wound is healed and *before* the optimum period for repair has passed. After wound healing has occurred, the surgeon is confronted with an elective and not an emergency procedure. He is not restricted, by the fear of potential infection, in the mobilization or transplantation of nerve segments if that should prove necessary. He is able to complete a technically facile suture through thickened epineurium without undue tension on the suture site and without forced joint flexion. Furthermore,

the accumulated experience of the war has shown that concomitant bone or tendon injuries are not contraindications to the deliberate and rational attack upon a severed nerve but that the sequence of therapy described is equally suited for the management of such combined injuries.

## SUMMARY AND CONCLUSIONS

The policy of early nerve surgery (within three to six weeks after wounding) as practiced for peripheral nerve injuries in the European Theater of Operations is outlined. The neuropathologic reasons for the selection of this period as the optimum time for reparative neurosurgery are stated. Sample results of the policy are presented, together with evidence of the far less good results accruing from the practice of primary nerve suture. The lessons derived from this experience are applied to civilian traumatic neurosurgery.

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DISCUSSION.—DR. CLAUDE C. COLEMAN, Richmond, Va.: Doctor Spurling, as chief consultant in neurologic surgery for the Army, has had a very unique and exceptional opportunity to collect and correlate the observations on peripheral nerve injuries in World War II. His extensive experience in the treatment of these injuries at the Walter Reed Hospital has given him first hand information as to the important technical points in the suture of divided nerves.

The most important thing we have to do now is to find out just what surgery of peripheral nerve injuries will accomplish and to transfer the lessons learned in war surgery to the treatment of such conditions in civilian practice. I think it is a mistake to accept the statement that treatment of nerve injuries of warfare is applicable entirely to nerve lesions in civilian life. Doctor Spurling thinks the optimum time for suture of a divided nerve is three to four weeks after injury. I shall not go into any discussion as to the propriety of such delay in gunshot wounds of peripheral nerves, but in cases in which the nerve has been divided by a sharp instrument there should be no question of infection after mechanical cleansing and, as there is very little nerve tissue loss, a very limited resection of the nerve is required to permit adequate suture. If the primary

treatment of the wound is in the hands of those experienced in nerve surgery, then it would seem advisable to suture the nerve. If operation is delayed for three or four weeks there will be retraction of the nerve ends and neuroma formation, so that nerve tissue must be sacrificed to get the nerve ends approximated satisfactorily. This means more extensive resection of the nerve and in most cases there will be tension on the suture line. In gunshot wounds of nerves the explosive force of the missile causes damage to the segments and it may be difficult at the time of primary treatment of the wound to determine just how much of the nerve ends should be resected. I have always sutured the divided nerve at the time I did the primary treatment of a wound when the injury was caused by a knife or other sharp instrument, and this practice has been satisfactory.

The most common nerve injury requiring suture that I have seen in civilian practice is that about the wrist joint. Unfortunately, the primary treatment of these wounds is often conducted by an inexperienced member of a hospital resident staff, and it frequently happens that the end of the divided nerve is sutured to a tendon. It takes an experienced nerve surgeon to treat median and ulnar nerve lesions which are often associated with tendon injuries.

From the nerve surgery of World War II, we hope to get some information of real importance. A great deal of time has been devoted to the details of technic. I do not consider it important whether the suture material is tantalum wire or fine silk, but what I want to know most is, just how much functional recovery one may expect from nerve suture. We want criteria of recovery formulated, and the results of peripheral nerve surgery of World War II matched with this criteria. Notwithstanding the fact that nerve surgery in this country has been conducted by men of experience whose work has been excellent, I am afraid the final results still are not as good as we would like.

DR. JOSEPH E. J. KING, New York, N. Y.: I want to congratulate Doctor Spurling and Doctor Woodhall and the members of the Neurosurgical Staffs for the magnificent work they have done in the field of peripheral nerve surgery, not only with reference to the suture itself, but to all the measures which have been adopted in connection with peripheral nerve surgery. They have had the added advantages of splendid coöperation from top to bottom, with plenty of money to carry out the work. Their transportation service has been the best in the world and their work has been excellent.

Now, with reference to the last war, I wish to state again that good work was done by all the men who had the opportunity to work on a Neurosurgical Service. The cases, as a group, were operated upon considerably later than those of the present time, due mostly to delayed transportation and, in a number of cases, associated infection. Therefore, the final results should be better in this war than in the last. I personally know that the work at Cape May and Fox Hills, under the leadership of Dr. Charles Frazier, was well done and splendid records were kept. These records probably are covered with dust somewhere in the Surgeon General's office. Although Doctors Coleman, Stookey, and others, wrote splendid papers dealing with peripheral nerve surgery, it seems that these made little impression on the doctors in civilian practice, and a number of the younger men apparently knew very little about what went on before.

When Doctor Spurling used the word "stigma" I feel sure he was not referring to the surgery done by men such as Doctors Frazier, Coleman, Stookey, Elsberg, and others, and I doubt seriously if there has been much improvement in the actual technic of suture of peripheral nerves, or in the ability of the men performing these operations. On the Neurosurgical Services at Cape May and Fox Hills the number of patients would average between 500 and 600 most of the time, and the majority of these cases were peripheral nerve injuries. It is inconceivable that men of such caliber as those mentioned could handle so many cases and not do the work well. Various of my former associates and friends who are now doing nerve sutures in the Neurosurgic Services of the Army and Navy, have informed me that they know nothing new about nerve suture, and that the technic is just about the same, in their experience, as what was done in the last war.

COL. ELDRIDGE CAMPBELL, Albany, New York: These are the figures we have been eagerly awaiting, and I think, on the whole, they are most reassuring. Early in the war many wondered why it would not be possible to perform nerve suture at the time of

primary débridement. When the present program of wound management was put in effect in MTOUSA (?) this question pressed all the more strongly for answer. With Colonel Churchill's approval, primary nerve suture was carried out in quite a number of cases during the Italian campaign. Subsequently, it was largely abandoned for the following reasons: In the first place, with high velocity missile wounds—and I qualify all these statements with that—it was not always possible to predict how far back along the nerve trunk necrosis would extend. I think I might cite one case which falls into the category of which Doctor Coleman spoke. A soldier was admitted within four hours after receiving a small wound to his arm, in which the median nerve was divided. An excellent surgeon performed débridement of the wound; the nerve lay exposed "asking to be sutured." This was done, the wound was closed and the arm splinted, and he was transferred to a General Hospital a few miles away, and on the fourth day skin closure was carried out. The operator could not resist the temptation to open the deep fascia, and found the ends had not only separated by a centimeter but were softened for a good centimeter on each side.

Another thing, all wounds do not heal *per primam*, particularly in compound fractures, and if one does a suture at the time and something happens, just that much more trunk is sacrificed. In the third place, one frequently has to extend the wound very considerably above and below to effect an anastomosis without tension. Finally, many times one does not like to carry out a procedure which will take up a table for an hour, unless one has reasonable assurance that the patient will be more benefited then than he will later, by so doing. So the program in the Italian campaign was to close the wound, to stabilize the fracture, and then after the wound had solidly healed to perform nerve surgery four or five weeks after wounding.

Why not perform neurorrhaphy at the time of secondary suture? At that time the nerve ends were often edematous; in the interim the tissues are quite edematous, and while that might not make much difference, certainly there is nothing to lose by waiting a little longer.

Just one more point concerning the care of nerve ends at the time of primary débridement in high velocity wounds. I believe at the end of the last war it was suggested that nerve ends be brought together with a stitch at the time of primary débridement so they would not retract and would be easier to find. I had the opportunity to see some of these four or five weeks later. It seemed to me that the extent of the neuroma, the amount of swelling and the lengths which had to be resected were just as great and sometimes greater than in those in which this had not been done. I noted another thing, that divided ends lying free in the wound at the time of secondary closure four to ten days later, not infrequently were covered with fibrin and swollen, but at the point where they were protected by muscle, the fibrinous coat was much less marked. Therefore, it became the practice to cover exposed ends with muscle or some other tissue at the time of débridement. This is often impossible following makeshift nerve suture at primary débridement, for the nerve may thus be drawn into the wound in such a way that it cannot be covered.

These are some of the reasons why the results of primary suture of nerves divided by high velocity missiles have not been as good as those obtained when performed four to six weeks later.

## MEDIASTINAL TUMORS\*

REPORT OF CASES TREATED AT ARMY THORACIC SURGERY CENTERS  
IN THE UNITED STATES

COLONEL BRIAN BLADES, M.C.

ONE HUNDRED AND NINE PATIENTS have been operated upon for mediastinal tumors at Army Thoracic Surgery Centers in the United States\*\* during a period of approximately three years. Numerically, the series seems meager when the potential patient population made up by millions of men and women in the military service is considered. Undoubtedly, the adoption of routine roentgenologic examination of the chest as a requirement for entrance to military service led to the detection, and immediate rejection, of many individuals with asymptomatic mediastinal tumors.

This report includes only cases in which either the clinical manifestations of an intrathoracic neoplasm or discovery of a mass in the mediastinum by roentgenologic examination after entrance on active duty resulted in surgical exploration of the chest. No attempt has been made to include all patients with mediastinal tumors treated in the United States Army or even in Thoracic Surgery Centers. Descriptions of neoplasms of lymphoid origin, namely, lymphosarcoma, Hodgkin's disease, lymphocytoma, *etc.*, have been omitted unless surgical intervention resulted from erroneous diagnosis.

*Types of Mediastinal Tumors.*—There were 94 benign and 15 malignant tumors in the group (Tables I and II).

### BRONCHIOGENIC CYSTS

Twenty-three bronchiogenic cysts have been removed from the mediastinum. It is of interest that this relatively rare lesion was encountered so often. Hare<sup>1</sup> found no record of bronchiogenic cysts in the mediastinum in 600 cases of mediastinal tumors recorded prior to 1899. In 1937, Alford<sup>2</sup> reported seven cases. Three years later, Heuer and Andrus<sup>3</sup> collected 25 cases from medical literature, and added one of their own. And, in 1945, Laipply<sup>4</sup> found that 34 cases of mediastinal cysts of the bronchial type had been reported, and described another case, making a total of 35 cases. Even if allowance is made for incorrect classification of cysts of the mediastinum, and one assumes that some cysts of bronchiogenic origin have not been so classified, it becomes apparent that these lesions are relatively rare.

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\*\* Baxter General Hospital, Spokane, Washington; Brooke General Hospital, San Antonio, Texas; Fitzsimons General Hospital, Denver, Colorado; Kennedy General Hospital, Memphis, Tennessee; and Walter Reed General Hospital, Washington, D. C.

The Chiefs of the Thoracic Surgery Sections at these hospitals are, respectively, Major Thomas B. Wiper, Major Donald L. Paulson, Colonel John B. Grow, Lieut. Colonel Richard H. Meade, Jr., and Colonel Brian Blades.

*Location of Bronchiogenic Cysts of the Mediastinum.*—The cysts may be located at almost any site along the tracheobronchial tree. In one case, not included in this series because the tumor was not in the mediastinum, a bronchiogenic cyst was located on the diaphragm, and there was no demonstrable connection between it and the lung or the mediastinum. When the mediastinum is involved, the most common location of the cyst is in the superior mediastinum near the tracheal bifurcation. The tumor may occupy either an anterior or posterior position. A patent lumen communicating with the trachea or bronchi could not be demonstrated in any of our cases.

TABLE I  
BENIGN MEDIASTINAL TUMORS

Type of Tumor	[No. of Cases]
Bronchiogenic cysts.....	23
Dermoids and teratomas.....	14
Primary nerve tumors.....	29
Pericardial cysts.....	10
Thymomas.....	4
Lymph nodes*.....	4
Lipomas.....	3
Thyroid adenomas.....	2
Esophageal cyst.....	1
Tuberculomas.....	2
Sarcoid*.....	1
Fibroma.....	1
Total.....	94

\* Biopsy of tissue, tumor not removed.

TABLE II  
MALIGNANT MEDIASTINAL TUMORS\*

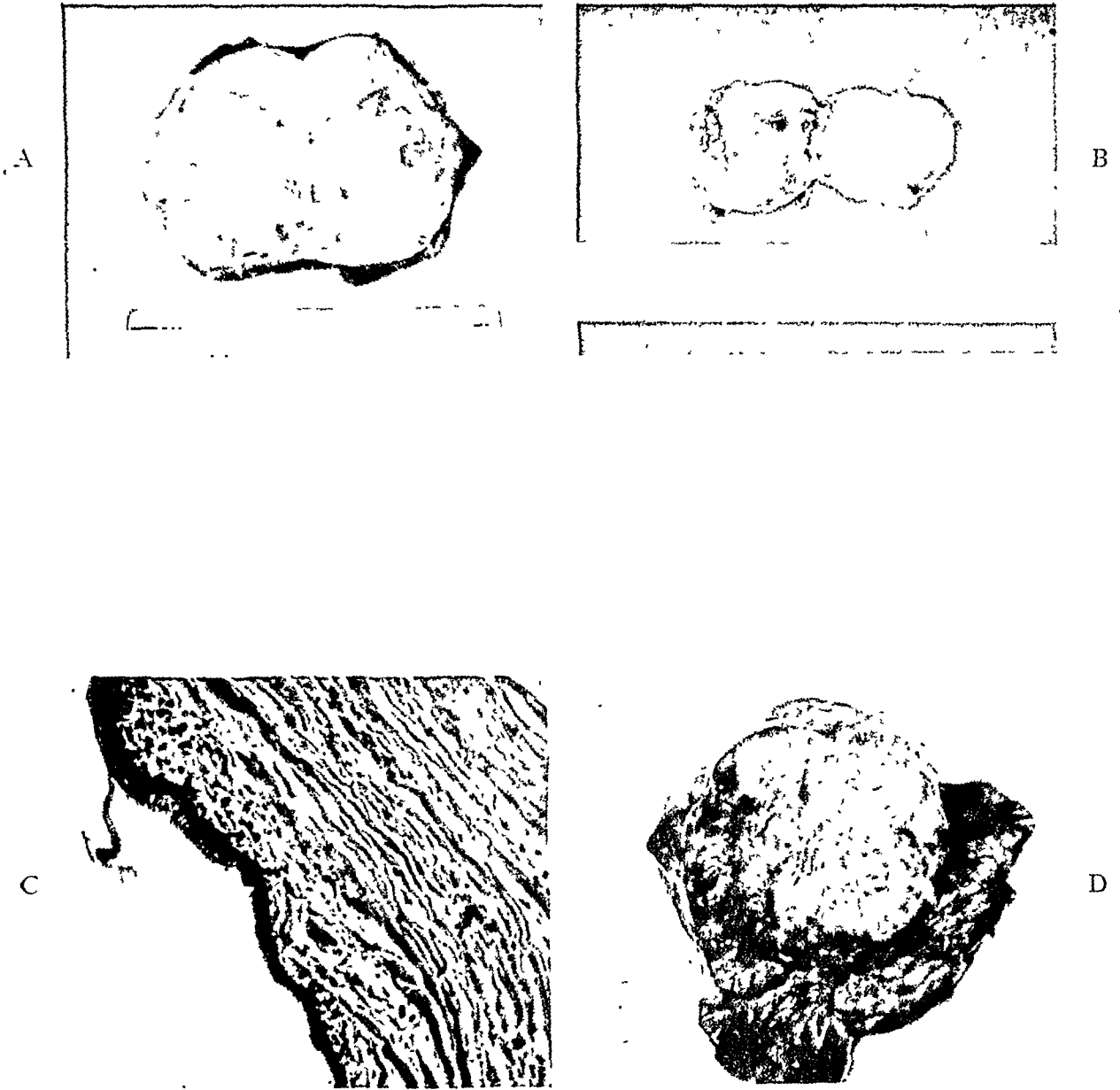
Type of Tumor	No. of Cases
Teratomas.....	6
Thymomas.....	2
Neurosarcoma.....	1
Lymphoblastomas.....	2
Hodgkin's disease.....	4
Total.....	15

\* Extensive invasion of the tumor precluded even partial removal in all except three cases.

*Clinical Manifestations.*—Pain in the chest is the most common symptom of a bronchiogenic cyst. The pain is usually not severe, and its location is often substernal. Another common complaint is cough. Only two of the 23 cases considered in this report had clinical manifestations of intrathoracic disease. The mass was detected on roentgenologic examination in the remainder of the group.

*Roentgenologic Examination.*—An accurate preoperative diagnosis of a bronchiogenic cyst depends almost entirely on roentgenologic examination. Even with careful roentgenologic examination, the true nature of the lesion is

PLATE I



- (A) Photograph of semi-solid bronchiogenic cyst of the mediastinum.  
(B) Photograph of thin-walled bronchiogenic cyst filled with mucus.  
(C) Microscopic appearance of bronchiogenic cyst.  
(D) Photograph of tumor and right middle lobe after removal.





difficult to establish. On the frontal projection the mass may resemble a teratoid tumor or a primary nerve tumor (Fig. 1). The lateral roentgenogram is of more diagnostic significance, however, since the extreme posterior position common in most primary nerve tumors will not be duplicated by bronchiogenic cysts and, usually, the shadow of the mass on the lateral projection is not so distinct as is the case with teratoid tumors. Brown and Robbins<sup>5</sup> have emphasized the importance of examination with the fluoroscope in establishing the diagnosis of a bronchiogenic cyst. Since most bronchiogenic cysts are attached to the trachea, the mass will move with the act of swallowing. This



FIG. 1.—Roentgenogram of bronchiogenic cyst.

can be demonstrated during fluoroscopy, and is of some significance as a diagnostic point. Roentgenograms made by the Potter-Bucky technic, visualization of the esophagus with barium sulfate to determine the relationship of the mass to the esophagus, delineation of the bronchial tree with radio-opaque oil, and other methods of roentgenologic diagnosis are sometimes useful.

*Gross Appearance of Bronchiogenic Cysts.*—Bronchiogenic cysts are round or ovoid masses, and may be located in any part of the mediastinum. They are usually attached to the carina or a bronchus by a stalk. It is sometimes very difficult to identify this attachment. The cysts may vary from thin-walled tumors filled with clear fluid to almost solid neoplasms (Plate I, A and B). Other descriptive terms which have been employed for these lesions are ciliated epithelial cysts and reduplication cysts of the respiratory tract.

All evidence suggests that bronchiogenic cysts are the result of developmental abnormalities, either from the pinching-off of a diverticulum of the foregut near the tracheal bud or a secondary development of the tracheal bud itself, resulting in an abnormal division of the tracheobronchial tree as growth proceeds. Similar theories have been suggested to explain the formation of esophageal, gastric and gastro-enteric cysts of the mediastinum. If these theories are accepted, it is understandable that occasionally a bronchiogenic cyst appears to be attached to the esophageal wall. Womack<sup>6</sup> has suggested that available evidence indicates that bronchiogenic cysts represent "a regional disorganization in the vicinity of the developing trachea and foregut."

*Microscopic Appearance.*—Bronchiogenic cysts may contain any or all of the tissues which are normally present in the trachea and bronchi. The walls contain fibrous connective tissue and sometimes mucous glands, cartilage and smooth muscle. Stratified squamous epithelium or more typically ciliated pseudostratified epithelium forms the lining of the cyst. The fluid in the cyst may vary from clear, water-like liquid to viscid gelatinous material (Plate I, C).

*Treatment.*—Unless the age and general condition of the patient precludes a major operation, the proper treatment of bronchiogenic cysts is surgical extirpation. If the cyst is not infected, removal is usually easy. Technical difficulties are increased by the presence of infection, but this complication makes operative interference imperative.

The objection might be raised that if the tumor causes no symptoms, it should be left alone. There are several excellent reasons why the watchful waiting policy cannot be applied safely in the management of mediastinal tumors. The most important one is that it is impossible to make a positive diagnosis of any asymptomatic mediastinal tumor before the mass is removed. Many neoplasms of the mediastinum which have grave potentialities of malignant change resemble bronchiogenic cysts on roentgenologic examination, for example, the teratomas and thymic tumors. There is also the possibility of the cyst becoming infected or increasing in size, producing pressure symptoms. No reliable data concerning the incidence of malignant change in bronchiogenic cysts are available, but these lesions may be considered correctly cell rests. There is no reason, therefore, to believe that malignant changes could not occur. It is quite possible that highly malignant tumors which in the past have been catalogued under the somewhat ambiguous term—"carcinoma of the mediastinum,"—may have originated in bronchiogenic cysts. These neoplasms are at least first cousins of the teratoid tumors, both developmentally and histologically. The frequency of malignant change in dermoids and teratomas is well known.

#### DERMOIDS AND TERATOMAS OF THE MEDIASTINUM

Harrington<sup>7, 8</sup> has simplified the terminology in discussing dermoids and teratomas of the mediastinum by employing the inclusive term—teratoid tumors. He chooses "teratoid" because most of these neoplasms contain elements of three germinal layers.

Twenty patients with teratoid tumors have been operated upon at Army

Thoracic Surgery Centers. In 14 cases the tumor was benign. Far advanced malignant changes were evident in six cases.

Teratomas and dermoids of the mediastinum are relatively common tumors. More than 245 cases are recorded in medical literature. With the exception of tumors of lymphatic origin, which are usually not treated by surgical removal, the teratoid tumors are the most common neoplasms of the anterior mediastinum. Teratoid tumors usually produce sharp and obvious roentgenographic

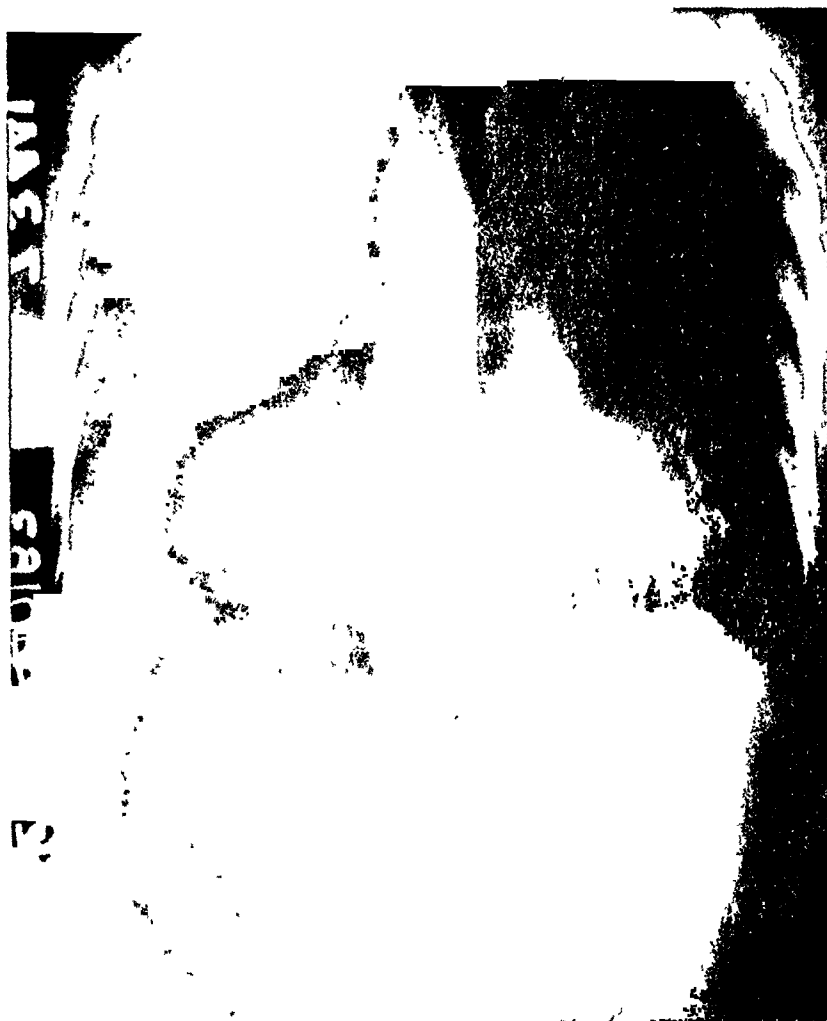


FIG. 2.—Laminogram showing teeth in teratoma.

shadows which are easily detected. The relatively low incidence of teratoid tumors in members of the military service is easy to explain. Discovery of the tumor on roentgenograms of the chest made at the time of induction examinations resulted in immediate rejection.

*Symptoms.*—Cough and chest pain are the most common symptoms. In one of our cases the tumor had invaded the right middle lobe of the lung. The patient was admitted to the hospital for the treatment of hemoptysis.

**Case 1.**—A 28-year-old woman was admitted to the hospital for treatment of hemoptysis. The history revealed that she had coughed up blood over a period of 15 years, and for the past two or three years had occasionally coughed up large amounts of pus. Roent-

genograms of the chest revealed a mass in the right lower chest. Visualization of the bronchi of the right lung revealed some bronchiectasis of the right middle lobe and, on bronchoscopic examination, pus could be seen coming from the middle lobe bronchus.

A diagnosis of teratoma of the mediastinum, with erosion into the right middle lobe, was made. Exploratory thoracotomy revealed a teratoma of the anterior mediastinum attached to the right middle lobe. A right middle lobe lobectomy was performed and the tumor was removed with the lobe. The postoperative course was complicated by the development of suppurative pleuritis. The empyema healed after adequate drainage (Figs. 2 and 3 and Plate I, D).

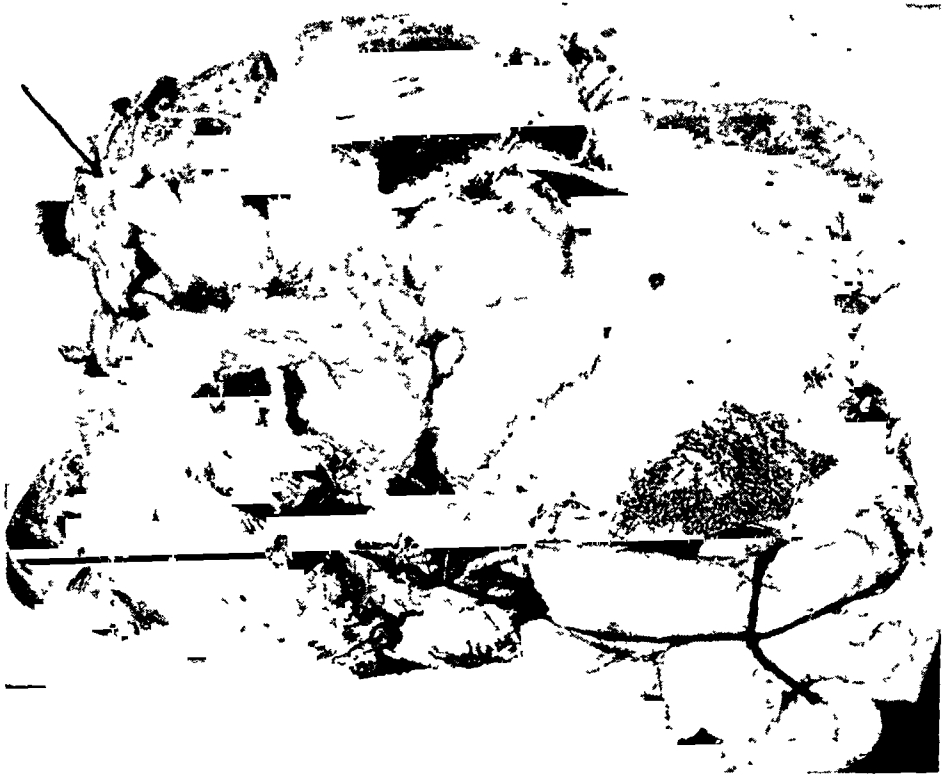


FIG. 3.—Photograph of tumor after section. Note teeth in tumor indicated by arrow.

Other clinical manifestations of teratoid tumors, including symptoms caused by pressure effects, namely, cough, dyspnea, and enlargement of the neck veins, are described in several excellent articles on dermoid cysts and teratomas of the mediastinum.

*Roentgenologic Examination.*—Unless teeth or bone are visible on the films, the exact diagnosis of the teratoid tumor cannot be made by roentgenologic examination. The characteristic anterior position of the mass is suggestive but not conclusive.

*Location and Gross Characteristics of Mediastinal Teratoid Tumors.*—Mediastinal dermoids and teratomas almost always occupy an anterior position. In fact, there are only three cases reported in which the mass was not in the anterior mediastinum. There is nothing particularly characteristic about their size or shape, and, as is the case with bronchiogenic cysts, the structure of

teratoid tumors may vary from thick-walled cysts containing fluid to solid tumors. Ectodermal derivatives, such as hair, skin or teeth, may form part of the tumor. Teratoid tumors are thought to take origin from cell rests. Bronchiogenic elements which are drawn into the thorax by the descent of the heart and diaphragm may account for the development of some of these neoplasms. Complex neoplasms with three embryonal layers, however, cannot be accounted for by this theory. Another popular hypothesis is that there is a second independent embryonal analage existing as a parasitic fetus *in fetu*. This theory would explain the complex teratoma while the monogerminal furnishes a satisfactory concept of the formation of a simple dermoid.

*Microscopic Appearance.*—Elements of the endoderm, ectoderm and mesoderm may be found in teratomas. Varying combinations of tissue from the digestive tract, respiratory system, thyroid or even thymus may be identified.

*Treatment.*—The treatment is surgical extirpation. Roentgenotherapy is of no value in the treatment of benign teratoid tumors and is probably equally ineffectual when malignant changes have occurred. The dangers of malignant degeneration are considerable. Laipply<sup>4</sup> has reviewed the literature and found that 28 (11.4 per cent) of 245 cases of teratoid tumors were malignant. Heuer and Andrus<sup>3</sup> report malignant changes in five of their 13 cases. Six of 20 tumors in this series had undergone malignant change and were hopelessly inoperable. The necessity for surgical extirpation of these neoplasms before they become malignant is obvious. Rusby,<sup>9</sup> in his excellent article on dermoids and teratomas of the mediastinum, has described the various therapeutic endeavors which were employed before radical surgical excision was reasonably safe. He also emphasizes that collective data place the incidence of malignant change at 12.9 per cent and, that once the conversion from benignity to malignancy has taken place, the possibility of successful treatment is remote.

#### PRIMARY NERVE TUMORS

Twenty-nine benign neurogenic tumors of the mediastinum, including neurofibromas, ganglioneuromas, sympathicoblastomas, *etc.*, have been removed successfully. One patient with a neurogenic sarcoma was operated upon, but invasion of surrounding structures precluded removal.

Neoplasms of neurogenic origin are by far the most common posterior mediastinal tumors. Kent and his coworkers<sup>10</sup> were able to collect 105 cases in medical literature.

*Clinical Manifestations.*—Benign primary nerve tumors are usually asymptomatic. Occasionally involvement of certain nerves may cause pain; if the sympathetic chain is involved, Horner's syndrome may be evident. Too often, however, definite clinical manifestations of intrathoracic disease indicate malignant degeneration of the tumor.

*Roentgenologic Examination.*—The roentgenographic shadow of a primary nerve tumor may be round, spherical or lobulated. The typical extreme posterior position of the tumor is characteristic. Roentgenologic examination should include studies of the spine for bone erosion and evidence of so-called dumb-

bell tumor. The shadow on the roentgenogram is usually sharply circumscribed, both on frontal and lateral projections (Fig. 4 and Plate II, A and B).

*Gross Appearance and Location.*—The characteristic extreme posterior position of primary nerve tumors of the mediastinum has already been mentioned in the discussion of the roentgenologic examination. It is of interest that only two examples of primary nerve tumor in an anterior location have been recorded in medical literature.

If the neoplasm arises in the intervertebral foramina and extends both into the spinal canal and out into the posterior mediastinum, there will be an hour-



FIG. 4-A

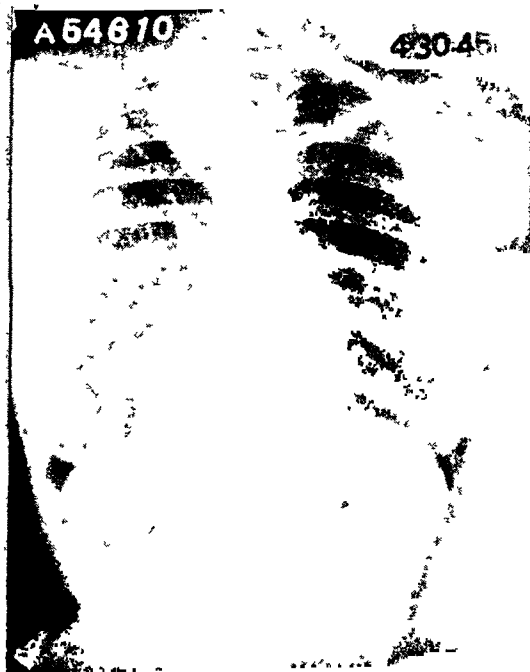


FIG. 4-B

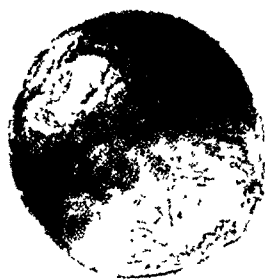
FIG. 4.—Roentgenograms showing typical posterior position of primary nerve tumors of the mediastinum.

glass or dumb-bell configuration. The extension into the spinal canal is seldom evident on roentgenologic examination, and may even be difficult to detect when the tumor is exposed at operation. This possibility must always be given careful consideration. The sites of origin of the tumor are commonly from the intercostal and sympathetic nerves, although any nerve may be involved.

*Microscopic Appearance.*—There is wide variance in the microscopic appearance of primary nerve tumors. Preponderance of fibrous tissue in some has resulted in the descriptive term—ganglioneurofibroma. In others, numerous ganglion cells can be seen, and these tumors are usually called ganglioneuromas. Lack of differentiation with cellular reticulomyxomatous tissue may produce a microscopic appearance compatible with myxoid neuromas. Frank malignant degeneration is seen in neurofibrosarcomas. The degree of malignancy is difficult to determine, either on gross or microscopic examination. All

PLATE II

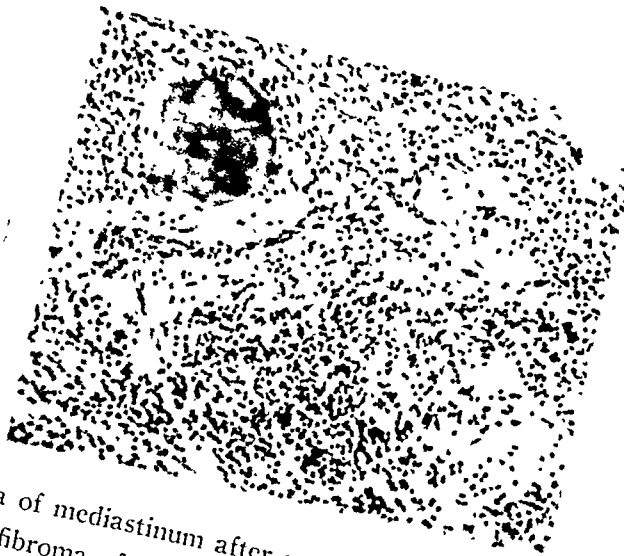
A



C



E



- (A & B) Photograph of neurofibroma of mediastinum after removal.  
 (C) Microscopic appearance of neurofibroma of mediastinum.  
 (D) Cut section of thymoma.  
 (E) Microscopic appearance of thymoma. Note Hassall's corpuscle.





primary nerve tumors of the mediastinum have a tendency to recur with increasing malignant characteristics if incompletely excised (Plate II, C).

*Treatment.*—Kent, et al.,<sup>10</sup> have reviewed the medical literature and studied the cases of neurogenic tumors of the chest seen at Graham's Clinic, in St. Louis. They found that 37 per cent of reported primary nerve tumors of the thorax had undergone malignant change. Forty-one per cent of the cases of primary nerve tumor of the chest seen at the Barnes Hospital, St. Louis, were malignant. Even if one assumes that a large surgical center would attract more difficult and complicated cases and that there has been a tendency to report malignant and complicated cases, it is apparent that primary nerve tumors are dangerous. Once malignant degeneration has occurred, the prognosis is grave and, in most cases, hopeless. The correct treatment is surgical excision before the tumor is malignant. Roentgenotherapy is futile in both benign and malignant varieties of neurogenic tumors.

#### PERICARDIAL CYSTS

Ten pericardial cysts are included in the series.

*Clinical Manifestations.*—Discovery of the tumor in all of the cases resulted from routine roentgenologic examination. The cysts were asymptomatic.

*Roentgenologic Examination.*—Except for their anterior position, there is nothing characteristic about the roentgenographic appearance of pericardial cysts to differentiate them from other mediastinal cysts.

*Location and Gross Appearance.*—Pericardial cysts are thin-walled structures, usually in contact with the anterior chest wall and the parietal pericardium. Occasionally, they may be large enough to impinge on the lung or diaphragm. Anomalous development of the pericardium probably explains their formation.

*Microscopic Appearance.*—The walls of the cysts are made up of fibrous connective tissue lined by a layer of flattened endothelial or mesothelial cells. It is probable that, in the past, some of these cysts have been classified as cystic hydromas or cystic lymphangiomas.

*Treatment.*—Since surgical extirpation is the only means of establishing the benignity of a mediastinal tumor, operation should be recommended. None of the patients included in this report complained of symptoms referable to the cyst. There is only one case reported in the literature in which symptoms were attributed to a pericardial cyst. Pickhardt<sup>11</sup> describes a patient who complained of persistent thoracic pain which was relieved when a pericardial cyst of the anterior mediastinum was removed.

#### THYMOMAS

Six tumors of thymic origin have been studied. In four instances the lesion appeared to be benign. One patient with advanced myasthenia gravis was operated upon by Lieut. Colonel Meade, at the Kennedy General Hospital. A malignant thymic tumor was found, and could not be removed completely.

*Clinical Symptoms.*—Four of the six patients with thymic tumors had no symptoms referable to the mediastinal mass. The neoplasms were discovered on roentgenologic examination.

**Case 2.**—The patient, a young Negro, complained of nervousness and inability to work. A diagnosis of psychoneurosis, anxiety type, had been made overseas and the patient was returned to the United States. A mediastinal tumor was discovered on a roentgenogram made during examination for separation from military service. Unfortunately, the patient's complaints were minimized, and prostigmine tests were not made before the operation. It was not until the neoplasm was removed and the diagnosis of thymic tumor established that my failure to appreciate the possibility of myasthenia gravis in this patient became so painfully apparent (Plate II, D and E).

*Roentgenologic Examination.*—There are no definite criteria for the positive diagnosis of thymic tumors. Hampton<sup>12</sup> has made the important observation, however, that in many cases the tumor has a tendency to maintain the shape of thymus, as seen in roentgenograms of children. Another suggestive finding is that often the tumor is easily seen in the frontal projection but is not so apparent on lateral roentgenograms. The thymus is a flat, thin structure. Even when its dimensions are distorted by tumor formation, the shadow on the lateral projection is difficult to detect.

*Location and Gross Appearance.*—Thymic tumors are usually located in the anterior mediastinum in the substernal position; however, in one case in our series, the neoplasm was situated posteriorly. The gross appearance may vary considerably. Characteristically, the tissue is of reddish-gray color. The tumors originate in the neck, are commonly in the superior mediastinum, but may extend almost to the diaphragm.

*Microscopic Appearance.*—The microscopic appearance of thymic tumors varies greatly. In benign lesions the cells may be composed of somewhat disarranged but otherwise practically normal thymic tissue. Some malignant thymomas may have the appearance of a malignant lymphoma, while others of the reticulum cell variety are made up of endodermal thymic reticulum cells. Still other malignant varieties resemble epidermoid carcinoma or teratoid tumors, depending upon which element of the thymus predominates.

*Treatment.*—Treatment may be either surgical extirpation or radiation therapy, depending upon the type of thymic tumor. The rôle of radiation therapy in the treatment of thymic tumors will be considered in the discussion of therapeutic management of all mediastinal tumors. If the lesion does not respond to radiation therapy, surgical excision should be undertaken.

#### LIPOMAS OF THE MEDIASTINUM

Only four mediastinal lipomas have been removed. This is not surprising, since less than 40 cases have been recorded in medical literature.<sup>13, 14</sup>

*Symptoms.*—Symptoms referable to lipomas of the mediastinum are those common to any mediastinal tumor, namely, pain, dyspnea or cough, depending upon the size and location of the mass. A long history of slowly progressing pressure symptoms may suggest a slowly enlarging fatty tumor.

*Roentgenologic Examination.*—There are no distinctive diagnostic features of the roentgenologic examination for lipoma of the mediastinum. Heuer and Andrus<sup>3</sup> were able to predict the true nature of a mediastinal lipoma in two of their cases because the shadow of the mass on the roentgenograms became less opaque toward the periphery. This finding suggested to them that

the tumor was composed of fat because it was more readily penetrable than the compact tissue of other tumors of the mediastinum.

*Location and Gross Characteristics.*—Lipomas of the mediastinum have been divided into three groups according to their location and form: (1) Tumors confined within the thoracic cage; (2) intrathoracic lipomas which extend upward into the neck; and (3) intrathoracic tumors with an extra-thoracic extension forming a dumb-bell configuration. In one case in this series there was extension into the neck.

*Microscopic Appearance.*—The microscopic appearance of a lipoma requires no comment.

*Treatment.*—Lipomas may grow to huge size. Watson and Urban<sup>14</sup> have recorded the successful removal of a lipoma which weighed 6.8 pounds. The same authors mention a case in which an intrathoracic lipoma, weighing 17 pounds and 6 ounces, was discovered at postmortem examination.

#### MISCELLANEOUS TUMORS

Other varieties of mediastinal tumors found in army personnel include: One tumor classified as a fibroma (probably a neurofibroma); one thyroid adenoma; two tuberculomas of the mediastinum; one cyst arising from the esophagus; and an osteochondroma of the mediastinum. In three cases, enlarged inflammatory lymph nodes were discovered when the chest was opened to establish the nature of an intrathoracic mass. And in one instance biopsy of tissue of hilar mass revealed Boeck's sarcoid.

#### MALIGNANT TUMORS OF THE MEDIASTINUM

Fourteen malignant tumors of the mediastinum were found; including six malignant teratomas, two thymomas, one neurosarcoma, two lymphoblastomas and four Hodgkin's disease. With the exception of three cases, it was impossible to remove the tumor. It is surprising, and interesting, that in three cases tumors were removed, which proved, upon microscopic examination, to be Hodgkin's granuloma. In one case, operated upon by Major Paulson, at the Brooke General Hospital, the tumor had invaded the upper lobe and it was necessary to perform an upper lobe lobectomy, when the neoplasm was removed.

In two instances mediastinal tumors of unknown origin were extirpated. Microscopic examination of the tissue revealed Hodgkin's disease. One patient was operated upon by Colonel Grow, at the Fitzsimons General Hospital, the other at the Walter Reed General Hospital.

**Case 3.**—The patient, a 27-year-old white male, had had three years and three months of active military service. He was first admitted to a hospital for the treatment of frozen feet, after evacuation from the combat zone to England. At that time there was no history of chest pain, loss of weight or other indications of intrathoracic disease. The condition of his feet made it necessary for him to be moved to the Zone of Interior. While on furlough after returning to the United States, he lost weight and occasionally had low-grade fever with night sweats. A roentgenogram of the chest revealed a mass in the posterior mediastinum (Fig. 5). The possibility of Hodgkin's disease was not considered seriously.

The thorax was explored through a right posterolateral incision. A large mass was found in the posterior mediastinum. The mediastinal pleura was dissected from the mass and the mass removed by sharp and blunt dissection. The tumor had a lobulated appearance and was obviously of a malignant nature. There were many palpable lymph nodes near the pulmonary hilum (Plate III, A, B and C).

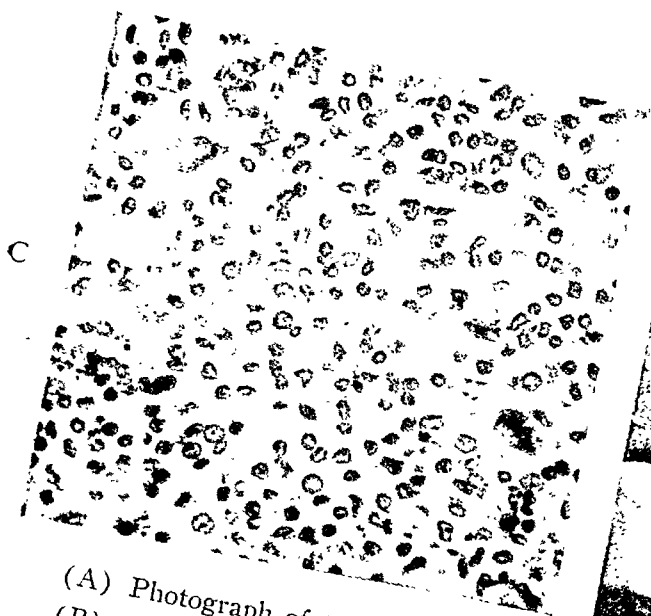
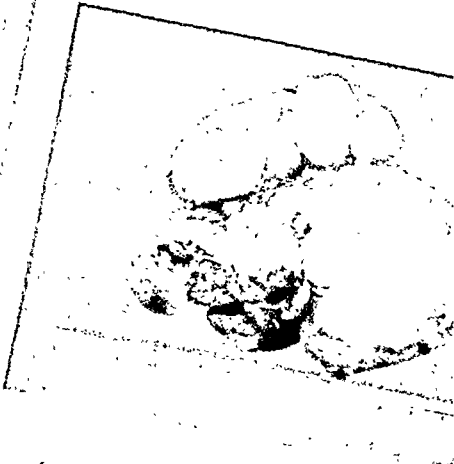
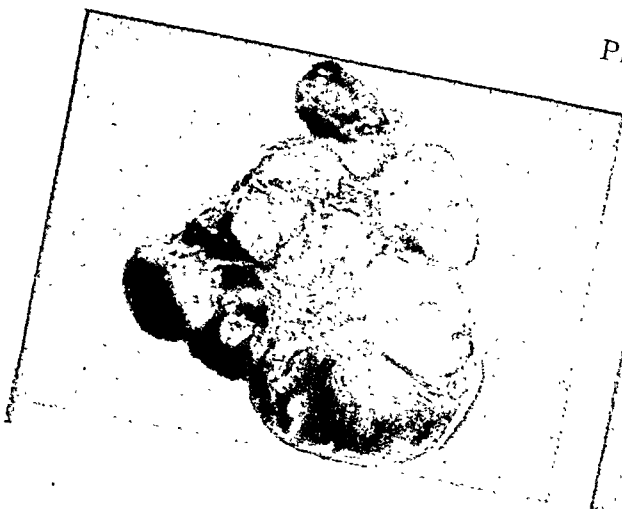
After excision of the mediastinal tumor, which proved to be Hodgkin's disease, radiation therapy was administered as soon as the incision of the chest wall had healed. During the following eight months, the patient gained 20 pounds. He has had no fever. There is no evidence of recurrence of the tumor on roentgenologic examination. He complains of some shortness of breath and occasionally notices a tight sensation in the chest.



FIG. 5.—Roentgenogram of tumor which proved to be Hodgkin's disease

In the similar case operated upon by Colonel Grow, at the Fitzsimons General Hospital, radiation therapy was withheld, and it is planned to administer it when there is sign of recurrence. This patient has been under observation for a period of approximately nine months, with no evidence of recurrence of the tumor. It should be emphasized that surgical intervention would not have been recommended in any of these cases had the true nature of the lesion been established. It appears, however, that these patients have not been harmed, and probably have been benefited, by having the visible tumor removed. No

PLATE III



- (A) Photograph of tumor after removal.
- (B) Cut section of mediastinal Hodgkin's disease.
- (C) Microscopic appearance of tissue.
- (D) Photograph taken at the operating table of exposure of a neurofibroma of the mediastinum by the posterolateral approach.



conclusions can be drawn concerning the results in any of the cases until they have been observed for a long period of time.

In the other cases of malignant neoplasms of the mediastinum, the tumor had invaded adjacent structures and the lesions were hopelessly inoperable. Tissue for microscopic study was obtained and the thorax closed.

#### RADIATION THERAPY AND SURGICAL TREATMENT OF MEDIASTINAL TUMORS

Unfortunately, there is no infallible method to determine preoperatively the exact nature of a mediastinal mass. Therapeutic endeavors are limited to radiation therapy and surgical removal. It is apparent, therefore, that the first decision which must be made is the choice between these two methods of treatment. For many years there has been a tendency to treat mediastinal tumors primarily by radiation therapy. If there was no effect upon the neoplasm, radiation therapy was abandoned and the possibility of surgical intervention considered.

Before refinements in operative and anesthetic technics made the exploration of the chest safe, this attitude was understandable. The accumulated reticence of physicians to recommend exploratory thoracotomy has probably resulted, however, in the injudicious use of radiation therapy in many cases.

Surgeons and radiologists experienced in thoracic disease should be able to predict in the majority of cases whether roentgentherapy will be successful. Even if errors in diagnosis occasionally result in thoracic exploration for tumors which will respond to radiation therapy, the danger to the patient from the operation is slight when compared to the deleterious effects of prolonged and ineffectual radiation therapy. Most benign tumors of the mediastinum and some malignant neoplasms are amenable to surgical removal. Radiation therapy will fail to reduce the size or to halt malignant degeneration of mediastinal tumors unless they are of lymphatic origin. Moreover, after prolonged exposure to roentgentherapy, the removal of the lesion will be more difficult and hazardous.

It is usually possible to make a tentative and reasonably accurate diagnosis of a mediastinal tumor of lymphatic origin. With few exceptions these are the only mediastinal tumors which will respond to radiation therapy. Neoplasms of lymphatic origin have a far greater tendency to produce clinical symptoms early and their roentgenographic appearance is fairly characteristic. If, after a test dose of roentgentherapy the neoplasm decreases in size, it can be assumed that it is of the lymphoma group and surgical intervention is not indicated. Properly employed, radiation therapy is invaluable, both as a therapeutic and diagnostic measure. Continued injudicious radiation, however, may be disastrous, and if after a fair trial the tumor is not affected, the method should be discontinued. Friedman,<sup>15</sup> at the Walter Reed General Hospital, recommends an initial test dose of 750 r delivered to the center of the tumor. It should be emphasized, however, that about one-third of malignant lymphomas will require as much as 1500 r to affect the tumor. If, after a period of approximately one month, there is no change in the size of the tumor, thoracic exploration should be performed to determine the exact nature of the lesion.



## EXPLORATORY THORACOTOMY

The choice between radiation therapy and surgical intervention will, of course, depend largely upon the risk of exploratory thoracotomy. It can be stated categorically that the danger of exploration of the mediastinum is trivial provided qualified anesthetists and surgeons are available and if the patient is in reasonably good general condition. If operation is delayed until signs and symptoms of pain, enlargement of the tumor, *etc.*, are apparent, the opportunity for successful extirpation of the lesion will usually have been lost.

The relative safety of a properly performed exploratory thoracotomy is demonstrated by our results, and the experiences of others. It is admitted that the majority of patients in our series are young men and are, therefore, good risks for major operations. In a total of 114 exploratory operations to determine the nature of a mediastinal mass (including five cases of aneurysms in which a correct preoperative diagnosis was not made), there were no deaths which could be attributed to the exploratory operation. There were no post-operative complications in patients upon whom an exploration and biopsy was performed. In three cases in which a tumor was removed, suppurative pleuritis developed. Adequate drainage of the empyema resulted in prompt healing. In one of these cases previously described, it was necessary to remove an infected right middle pulmonary lobe which had been eroded by a teratoma.

## OPERATIVE TECHNIC

Ordinary fundamental principles of surgical technic apply to the extirpation of mediastinal tumors. Adequate exposure and precise, gentle handling of tissues is especially important.

One controversial detail in surgical technic is the route for effecting entry into the thorax. Some surgeons employ routinely the posterolateral approach to remove mediastinal tumors. Others prefer an anterior approach for tumors situated in the anterior mediastinum and reserve the posterolateral approach for lesions situated posteriorly. It is interesting that in the five Thoracic Surgery Centers in the Army there was never complete agreement concerning the preferable method for exposing a mediastinal tumor. Paulson, at the Brooke General Hospital, reflected his early training with Harrington by using a posterolateral approach for practically all mediastinal tumors. At the Fitzsimons, Kennedy and Walter Reed General Hospitals both the anterior and posterior incisions were employed, depending upon the location of the tumor. There is complete agreement, however, that if technical difficulties are anticipated, the anterior approach may provide inadequate exposure and a lateral or posterolateral incision is preferable (Plate III, D).

The surgical removal of benign mediastinal tumors is usually relatively easy. Huge benign tumors occasionally present difficulties. If the neoplasm has undergone malignant change, surgical removal is usually impossible. Even if a malignant tumor can be removed, the operation is often only a palliative measure.

*Anesthesia.*—Details of anesthetic technic and a discussion of the various

anesthetic agents is not in the province of this report. Unhurried and safe surgery in the thorax requires expert anesthesia. The proper administration of intratracheal anesthesia makes the exploration of the chest and mediastinum as easy and as safe as exploration of the abdomen.

#### SUMMARY AND CONCLUSIONS

One hundred and fourteen explorations of the thorax have been performed at Army Thoracic Surgery Centers to establish the nature of mediastinal masses. In five cases the mediastinal tumors proved to be aneurysms. Biopsies of benign inflammatory lesions were obtained in five instances. Eighty-nine benign tumors of the mediastinum were removed successfully. In three of 15 cases of malignant tumors of the mediastinum, the mass was removed. In the remainder of malignant tumors, extirpation of the neoplasm was impossible. There were no deaths attributable to exploration of the thorax. All patients with benign tumors recovered promptly and returned to full activity.

Mediastinal tumors are relatively rare lesions, yet the routine roentgenologic examination of the chest has led to the detection of 94 of 109 cases of mediastinal tumors in this series. It is apparent that if this large number of neoplasms of the mediastinum were found in apparently healthy young men that the universal application of routine roentgenologic examination of the chest in individuals of all ages would result in the early diagnosis of many intrathoracic tumors. It should be emphasized again that if the diagnosis of a mediastinal tumor must wait until clinical manifestations are obvious, the chances of cure become remote.

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DISCUSSION.—DR. ALTON OCHSNER, New Orleans, La.: It is with considerable trepidation that a civilian discusses a paper dealing with Army experiences. It is heartening to see this material brought to the attention of the medical profession, because in the past these cases have not been treated correctly, largely because we did not know how they should be treated, and we instituted watchful waiting. As Doctor Blades pointed out, many patients developed malignancies, many developed infection, both conditions which greatly interfere with the removal of the tumor. If the mediastinal shadow is bilateral, it is more likely to be lymphoblastic. In the bilateral lesion, one is much more justified in employing roentgenotherapy before exploration. In unilateral shadows thoracic exploration, we feel, is justified early. We have treated four patients with unilateral mediastinal shadows in whom at operation a very small bronchiogenic carcinoma was found and, although the primary neoplasm was too small to be detected preoperatively, the involvement of the mediastinal nodes was massive and produced the mediastinal shadow.

I am happy that Doctor Blades has emphasized that any mass in the mediastinum which cannot be diagnosed definitely ought to be explored, because this is safer than procrastination.

DR. NATHAN A. WOMACK, St. Louis, Mo.: This presentation of Doctor Blades is very modest, and I think needs no comment. This huge series of intrathoracic tumors represents a most unusual experience, and the operative results speak for themselves. There is one point that I should like to make, having to do with the etiology of the so-called teratoma or dermoid of the mediastinum. Doctor Blades has referred to bronchiogenic cysts and bronchiogenic tumors of the mediastinum. I think his terminology is a good one. In times past, the explanation offered for these tumors has been most fantastic. It has been suggested that they have been caused by inclusions of skin into the anterior mediastinum during the formation of the anterior thoracic wall; that they represent misplaced blastomeres; that they were the result of misplaced sex cells. Such explanations are embryologically untenable. I think we have enough evidence now to show that these tumors, for the most part, represent the abnormal development of supernumerary lungs which takes place very early in embryonic life. I shall not offer our proof for this belief at this time, but will reserve that for later publication.

DR. PAUL B. MAGNUSON, Chicago, Ill.: It is quite appropriate that an orthopedic surgeon should discuss this paper, because he cannot be expected to know anything about the subject. However, Doctor Blades' paper was very instructive to me and was beautifully presented. He mentioned that 35 cases of a certain type of mediastinal tumor had been reported in the world literature up to this time, and then reports 23 additional cases operated upon by surgeons in the Army within a period of three years. These were diagnosed in a large percentage of cases, suspected in a small percentage, and produced in all cases at the operating table, with a minimal mortality.

When we consider that this has occurred in what was originally a select group of young men, how many cases have existed that have never been diagnosed nor reported? How many will be found in the millions of men discharged from the Army, to be cared for by the Veterans Administration? The possibilities of saving lives and preventing disability through proper examination radiologically, and otherwise, are perfectly enormous. If we can place these patients into the hands of doctors who know the possibilities, who know how to make an expert examination and who are furnished with the tools with which to work, undoubtedly in all branches of our various specialties there will be found cases which have been considered rare in the past; these will be brought to successful cure by a combination of personnel, equipment and placement, namely, medical schools, properly equipped and properly run hospitals located on the campus

of our universities. This the Veterans Administration is planning to do. The whole problem is now up to the medical profession—to take care of fifteen million men over a period of the next 50 years. It is a tremendous undertaking. It offers a challenge to the medical profession which it is ready to accept and which, as a matter of fact, it has advocated. The Veterans Administration wants to give medical service of the highest type and asks your help in putting the plan into effect. God knows we need this help. This time we must not fail the veterans. The Veterans Administration is determined that the treatment of these men shall be in the hands of the best physicians in the country, and they, as represented by the Specialty Boards, the College of Surgeons, the College of Physicians, the American Medical Association and its component societies, have all given ample evidence so far that their desire is to be of service in this undertaking, not for a year or two, but permanently.

LT. COL. BRIAN BLADES, Washington, D. C.: Our ideas concerning roentgenotherapy are completely in accord with those expressed by Doctor Ochsner. I would not presume to prescribe the amount of this therapy to be employed as a test dose. It is important to remember, however, that pulmonary fibrosis caused by intensive radiation may make the cure worse than the disease. Friedman, at the Walter Reed Hospital, usually gives 750 R. delivered to the center of the tumor, in cases in which the tumor appears to be of lymphatic origin. About 25 per cent of cases of Hodgkins' disease will require as much as 1,500 R. to affect the neoplasm. If as much as 1,500 R. has been given, Friedman recommends waiting approximately one month and, after this period of observation, the chest should be explored if the tumor has not decreased in size.

# ANGIOMATOUS MALFORMATIONS OF THE BRAIN\*

## SUCCESSFUL EXTIRPATION IN THREE CASES

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IN 1928, Cushing and Bailey<sup>1</sup> wrote regarding the "venous angiomas" of the brain: "The surgical history of the reported cases shows not only the futility of an operative attack upon one of these angiomas but the extreme risk of serious cortical damage which it entails . . . the lesions, in short, when accidentally exposed by the surgeon, had better be left alone. . . ." Again, the same authors stated of the "aneurysmal angiomas": "To extirpate one of these aneurysmal angiomas in the active state would be unthinkable and so far as we are aware there is no report in the literature of the attempt having been made."

In the same year, Dandy<sup>2</sup>, who preferred to call all of these lesions "arteriovenous aneurysms," wrote: "an aneurysm (*i.e.*, *arteriovenous* aneurysm) in the left hemisphere in a right-handed person is surely *noli me tangere* under all conditions . . . (in the right hemisphere) radical ligations or extirpations alone are curative, but are exceedingly dangerous to life and function and indicated in the minority of cases."

Among the 16 cases of Cushing and Bailey, and the eight cases of Dandy, no successful radical removal of the lesion was reported, nor was any such successful procedure discovered by these authors in their extensive reviews of the literature.

Since these two publications in 1928, many improvements in neurosurgical technic have been developed and a somewhat bolder attitude has sometimes appeared in the literature.

In 1933, Bailey<sup>3</sup>, in discussing the venous angiomas, stated: "In at least one case, radiation so reduced the vascularity that it was possible at a secondary operation successfully to extirpate the central lesion," but he does not state by whom or give other details of the case.

Mixter,<sup>4</sup> in 1941, attempted the removal of a calcified angioma of the occipital lobe, but was forced to discontinue the procedure before the removal was complete. Ray<sup>5</sup>, also in 1941, reported exposure and decompression in four cases, but nevertheless stated: "Direct operative attack upon the lesions is dangerous, but might be indicated in selected cases."

In the same year, Northfield<sup>6</sup> advised against any such radical procedure: ". . . the dangers of fatal hemorrhage and of extensive damage to the brain . . . forbid any attempt."

A single outstanding exception to this pessimistic attitude was the symposium on vascular tumors of the brain published by Bergstrand, Olivecrona and Tonnis.<sup>7</sup> Few details of individual cases were given but Olivecrona had

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successfully carried out the radical extirpation of cerebral vascular lesions associated with cutaneous naevi (Sturge-Weber's syndrome) in two cases and of "arteriovenous aneurysms" in three. Tonniss had removed one "angioma racemosum venosum."

Since the author believes that it is not only feasible but highly desirable to attempt radical extirpation of some of these formidable lesions, it seems wise to report three cases, in all of which such a procedure has been successful. These are the only instances in which true intracranial angiomas have been encountered. To be sure, large anomalous veins are sometimes seen on the cerebral cortex and have several times been ligated or coagulated in the hope of alleviating a convulsive state. The three lesions reported here, however, were not only vascular anomalies, but were *tumors*, in the space-occupying sense of the word. Their pathologic nature will be discussed later.

#### REPORTS OF CASES

**Case 1.**—G. S. (Vanderbilt University Hospital No. 102874): A 12-year-old Negro girl, was admitted from the Out-patient Department on November 6, 1939, because of convulsive seizures. Her first attack occurred at the age of 15 months. Thereafter, they came with steadily increasing frequency until at the time of admission, four or five or more seizures occurred each day. Many attacks were nocturnal, but there was no hour of predilection. She stated that she usually had a "peculiar feeling" immediately preceding the seizures, but could not describe this sensation. In the attacks, her head and eyes moved directly upward and tonic and clonic movements of the upper extremities occurred without predominance of either side. The lower extremities were seldom involved, but she had fallen on a few occasions. She seldom lost consciousness and could sometimes respond to questions during a seizure. Attacks usually lasted from a few seconds to two minutes. During the four years prior to admission, she had been incontinent of urine during nearly all attacks, but she had not injured herself. She stated that at times she had seen "animals" which she could not describe during attacks. She could not lateralize these visual phenomena.

There were no residual symptoms following attacks. Her development had been normal physically and she was in the seventh grade at school.

She had been born at full term following a normal delivery. There had been no injuries or significant illnesses. Her father had died of pulmonary tuberculosis one year prior to admission.

**Physical Examination:** The patient was a large, well-developed Negro girl, who was intelligent, alert and coöperative. Her memory and speech were normal. The head was well-formed. No bruit was audible. The optic disks were normal. The visual fields showed no defect. The neurologic and general physical examinations were completely negative. There were no cutaneous vascular lesions. Red, white and differential blood counts were normal. Urine and stool examinations were negative. The cerebrospinal fluid was under a pressure of 140 mm. of water and contained 2 cells per cu. mm. The total protein was 19 mg. per cent. The blood Kahn and the cerebrospinal fluid Wassermann were negative. The tuberculin test was strongly positive.

Roentgenograms showed an area of worm-like calcification occurring in thin double lines in the right occipital lobe immediately adjacent to the midline (Fig. 1).

The diagnosis was angiomatous malformation of the right occipital lobe. Because of the child's very frequent convulsions, radical removal of the lesion was advised.\*

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\*Electro-encephalograms, had they been available when this child was seen, would have been of interest. However, there seemed little doubt of the causative relationship of the calcified lesion in the production of the convulsions, and this has been borne out by the postoperative course.

*Operation.*—November 9, 1939: Under intratracheal ether, an osteoplastic flap was reflected to expose the right occipital lobe. The following is quoted from the operative note: "The dura was then very carefully opened close to the lateral sinus posteriorly and the dural flap turned back medially up to the sagittal sinus. The cerebral convolutions were flattened and the vessels on the surface of the brain extremely distended and somewhat tortuous. The outer aspect of the calcified area seen in the roentgenogram could at once be recognized by the greyish appearance of the pia along the vessels and the hard gritty consistency on palpation. Several veins which entered the sagittal sinus were carefully coagulated and divided. It was then possible to retract the occipital lobe laterally



FIG. 1.—Case 1: The worm-like tangle of parallel lines of calcification lies on the medial surface of the occipital lobe.

and to follow down the calcified area along the medial surface of the hemisphere. This extended completely to the splenium of the corpus callosum. At this point, entering vessels were seen and it seemed likely that the calcification had occurred in the extremely vascular tissue around the mass of blood vessels which could be seen on the medial surface of the occipital lobe. There was no specific demarcation of the involved area and no reason to think that the lesion could be removed as a separate entity. I first removed a small cortical portion of it for microscopic study but this could be done only with great difficulty, the application of several silver clips and coagulation of numerous vessels. An attempt to go deeper into the hemisphere through this small cortical defect was met with profuse bleeding. I, therefore, was faced with the choice of backing out and leaving the child unimproved, or amputating the entire occipital lobe. Since the only defect to be attained from the latter procedure would be a left homonymous hemianopia, I decided to do this. The cortical vessels were coagulated along a line well anterior to the lesion and extending laterally to the temporal lobe. The incision was then made with the electric knife and was carried straight down the medial aspect of the hemisphere to the splenium of the corpus callosum. The occipital lobe was then completely resected, insofar as the posterior and medial aspects were concerned but no attempts were made to go far antero-laterally. When the lobe had been removed there was profuse bleeding in the depths of the cavity, but by means of suction and coagulation the large artery was found and con-

trolled. I presume that this was the posterior cerebral artery. There was surprisingly little bleeding from elsewhere and this was easily controlled."

The usual closure was carried out in layers with fine interrupted silk. Blood loss had not been great and the patient's condition was satisfactory but she was given a transfusion at the end of the procedure.

*Course.*—The patient's recovery was prompt and uneventful. The presence of left homonymous hemianopia was evident as soon as she recovered consciousness and this was confirmed by perimetry on the 11th postoperative day. On that occasion and on numerous subsequent examinations, macular vision was found to be intact with no evidence of splitting. She was discharged on the 14th day, and returned regularly thereafter.

On all visits she was free of symptoms except for the hemianopia until March 5, 1940, four months after operation, when she was found to have a draining sinus in the line of incision and roentgenograms showed osteomyelitis of the bone flap (the wound had appeared to be completely healed on all previous visits). She was readmitted to the hospital and the bone flap removed, with complete healing after a period of drainage.

She has again been followed regularly until the present time, six years after operation. There has not been a single convulsion or other symptom of cortical irritation. The left homonymous hemianopia has persisted. Central vision has remained at 20/30 in each eye.

*Pathology.*—*Gross:* The excised occipital pole was discolored by subpial and subcortical hemorrhage on its medial aspect resulting from the biopsy and attempt at isolation of the lesion. The tortuous calcified vessels could be seen and felt to occupy a triangular area with its apex extending anteriorly and inferiorly on the medial surface of the lobe. The principal arterial supply certainly entered at this deep and anterior point and the venous drainage was largely through veins entering the longitudinal and lateral sinuses. No large vascular connections extended laterally.

When the lobe was sectioned, the gritty sensation resulting from calcification was felt to a depth of about 1 cm. from the medial surface. In the area of actual involvement by the lesion, the cerebral tissue was firm and rubbery, whereas the adjacent occipital tissue had a normal soft consistency.

*Microscopically,* the lesions in all three of the patients were quite similar and this aspect of their pathology will be discussed later in this paper.

**COMMENT:** The fact that the venous drainage of this lesion had to be occluded before its arterial supply could be exposed undoubtedly contributed to the difficulty of the procedure. Moreover, in retrospect, it was unwise even to attempt to isolate the lesion itself.

Since this patient was having four or five convulsive seizures daily, there can be no doubt that the complete postoperative freedom from attacks has justified the production of her homonymous hemianopia.

**Case 2.**—P. S. (Vanderbilt University Hospital No. 113219): A 12-year-old white girl, was referred by Dr. C. C. Howard of Glasgow, Kentucky, and admitted on March 27, 1941. She was right-handed. She had always been a healthy child. Sixteen months before admission, she had fallen from a bicycle, possibly striking her head, but not being rendered unconscious and having no residual symptoms. One year prior to admission, she had the first of a series of convulsions, while at school. Black spots appeared in front of her eyes, her right arm, hand and face felt peculiar, the fingers of the right hand began to twitch, the right arm jerked violently and this jerking spread to the right face and right lower extremity. She did not lose consciousness. The convulsive movements lasted two to three minutes. After the seizure she was drowsy and slightly confused, but could speak distinctly.



Similar attacks had occurred about every four weeks until admission, except for a period of three months during which no seizures took place. All attacks showed the same right-sided pattern, and never involved the left side. Consciousness was lost in two particularly severe convulsions. Speech was never known to have been disturbed. There were no residual symptoms following any attack, but for the three months prior to admission, the parents had thought the child to be somewhat apathetic, unable to concentrate as well as formerly and a little slow in cerebration. Nevertheless, she made good grades in school, played normally and did not complain of headache, visual disturbance or other neurologic symptom.

The breasts had begun to enlarge and pubic and axillary hair had appeared, but she had not begun to menstruate. She had been treated with some form of endocrine injections.

*Physical Examination.*—The patient was a thin, but intelligent, alert and cheerful girl, apparently just entering the menarc. The head was slightly asymmetrical due to a prominence in the left frontal area just above the hair line. This portion of the skull seemed a little protuberant but there was no localized mass and the area was not tender, red or fluctuant. No bruit was heard. The neck was not stiff and the general physical examination revealed no abnormality.

Memory was excellent and speech was normal. There was excellent enunciation, ability to read, to understand written and spoken speech and to write.

The optic disks, visual acuity and visual fields were normal. There was no abnormality of any other cranial nerve. Motor and sensory function were normal and equal on the two sides. No reflex abnormality could be demonstrated. Coördination, gait and station were normal.

Routine laboratory observations were normal throughout. Glucose tolerance curve was not abnormal. The cerebrospinal fluid pressure was 180 mm. of water. The fluid was clear and colorless and contained 6 cells per cu. mm. The total protein content was 55 mg. per cent. The Wassermann tests on blood and cerebrospinal fluid were negative.

Roentgenograms showed a thin skull, with normal sella turcica. In the left frontal area were two very thin incomplete circular lines of calcification, one quite large, relatively superficial and occupying at least one-third of the frontal area, the other smaller, deeper and medial to the larger. The appearance was that of calcification in the thin walls of two sacs (Fig. 2, above).

It was thought that the patient had some form of obscure cystic cerebral disease. All attempts to demonstrate any infections or parasitic systemic disorder failed. Operative removal of the lesion was advised.

*Operation.*—April 1, 1941: The following is quoted verbatim from the operative note: "Under ether anesthesia, a rather large left frontal flap was outlined and turned down. The skull was very thin and in some places actually had a rubbery flexibility. The prominence in the lower left frontal region, which had been visible and palpable from the outside, was due to an actual bulging of one of these thin and flexible areas of bone. When the bone flap had been turned down, the dura was also found to be very thin and very tense. A horseshoe incision was made in the dura with the base toward the midline. As the dural flap was reflected, it was found to be lightly adherent to the cortex in a number of places. These adhesions however were not vascular and were easily divided. When the dura was opened, a very remarkable appearance was presented. At the anteromedial border of the flap was a mass of enormous, tangled, tortuous vessels. The arachnoid about these was dense and opaque. Inferior to this mass was a fairly well-circumscribed bulging of the cortex about 5 cm. in diameter. This portion of the cortex was grayish-yellow in appearance and on palpation was very firm. There was obviously a hard underlying mass. After coagulation of the surface vessels, an incision was made in this area through the pia. This was fortunately done with the point of a knife rather than with the electrosurgical knife because the cortex turned out to be not more than 2 mm. in thickness, and beneath it there bulged a smooth reddish-purple mass which was fluctuant



FIG. 2.—Case 2: Above: Roentgenogram showing the thin lines of calcification outlining the tremendous venous sacs. Below: Photograph of specimen removed at operation. The walls have collapsed and have been loosely filled with cotton.

and obviously represented a saccular aneurysm. It did not pulsate and was thought probably to be a venous sacculatation. I thought very seriously of simply closing the child's head and considering the case hopeless because of the tremendous danger of fatal hemorrhage that would exist if removal of the lesion were attempted. However, the mass was so



FIG. 3.—Case 2: Drawing made at operation. The two venous sacs appear above and to the right. The mass of arteries below is partly concealed by opaque, thickened pia-arachnoid. Line A-A represents the midline and point B the drainage of the principal vein into the displaced sagittal sinus. (The cortical vascular pattern is not accurate—see text.)

huge and the brain bulging so badly that I felt that removal would be necessary if the child were to survive. Accordingly, with great caution, dissection of the greatly bulging purple mass was begun. Only a few tiny vascular connections existed with the surrounding brain below, and it was ultimately freed completely except for its anteromedial aspect where it obviously communicated with the mass of vessels described above. The lesion was then attacked from above and medially. In order to do this, it was necessary to make two small incisions across the midline reflecting a small flap of scalp toward the right side. The bone was then rongeuired away completely across the longitudinal sinus. The latter was pushed far beyond the midline by the great lesion. I also had to remove

considerable additional bone anteriorly in an effort to gain control of the series of large arteries entering the mass from the middle cerebral distribution. When this had been completed and the dura opened actually to the sinus, it was seen that the large mass of veins culminated in a huge confluent channel which entered the sinus at only one point (Fig. 3). I could not be certain that other connections with the sinus did not come from the deeper portions of the longitudinal fissure, but I did not dare try to find out because it would have been fatal to obstruct the venous outflow before gaining control of the arterial inflow. Three large arteries entering the superficial vascular portion of the lesion from an inferior direction were controlled with silver clips and were divided between the clips. One of them broke loose but fortunately was easily controlled by coagulation and application of another clip. The pia was then divided in a semicircular line extending from the large mass anteriorly and medially along the border of the vascular superficial mass. When this line of incision was dissected more deeply, there appeared another globular mass lying beneath the tangled vessels. This was much smaller than the first one and evidently communicated directly with the latter. Gradually the dissection was carried deeper and deeper until the lesion was very nearly free except for its medial connection and except that I could not yet define accurately the connection between the large and small masses. At this location, gentle dissection was being carried out, when the lesion suddenly ruptured and there was an enormous flow of bright red blood. Quite obviously only a few seconds of this hemorrhage would have exsanguinated the child. Accordingly, a finger was inserted laterally and the entire mass which was already nearly free was turned on its central hinge. When this was done, the medial connections were torn and the entire lesion came away in one piece. The tremendous flow of blood gushed from two points—the one, the opening in the sinus which was seized between thumb and index finger and easily stopped; the other, a large artery, probably a branch of the anterior cerebral on the medial border of the hemisphere. Fortunately, I succeeded in grasping this with a bayonet forceps. Thus the hemorrhage was controlled within a few seconds of its beginning and the loss of blood, although alarming was controlled sufficiently quickly to avoid exsanguination of the child. Two silver clips were placed on the torn artery. The great vein entering the sinus was seen to have retained a small cortical connection and fortunately had not torn a hole in the wall of the sinus. It was, therefore, easy to apply silver clips with satisfactory control. There were several other small vessels which bled a little bit and which were easily controlled. When bleeding had ceased a transfusion was begun and the great yawning cavity inspected. At its bottom lay a smooth membrane which turned out to be the ependyma of the ventricle. By elevating the cortical margins, the choroid plexus could be seen posteriorly. The cavity was filled with saline and the dura closed tightly. Because of the removal of so much additional bone, the flap could not be held in place satisfactorily. I thought of securing it with wire or heavy silk thread but even then it would have fallen inward too much. It was removed from its periosteal attachment and set aside perhaps to be replaced later. Fortunately, it was possible to close the periosteum throughout almost the entire extent of the wound. The remainder of the closure was carried out as usual with interrupted silk throughout. A gutta percha wick was left in a small stab wound at the posterior border of the flap."

*Course.* Following operation, there were transitory motor aphasia and right hemiplegia, both of which were greatly improved on the second postoperative day. The wound healed promptly. At the time of her discharge on the 16th day, speech was normal and a slight right facial weakness was the only residual motor sign. The deep reflexes were still more active on the right than on the left, but the Babinski was negative and there was no clonus.

The child has been seen regularly until the present time (Fig. 4). For three months there were no symptoms, but, on July 6, 1941, she had a typical jacksonian seizure similar to the preoperative attacks. She was placed on anticonvulsant medication and since that time has had widely spaced minor attacks of "numbness" and sometimes

clonic twitching of the right hand and arm. Slight residual weakness of the right hand is present and, when excited, she sometimes has transitory difficulty in speaking.

*Pathology.* The large mass described in the operative note consisted of a single tremendously dilated vein. When empty and collapsed, it still measured  $11 \times 5 \times 5$  cm. (Fig. 2, below). Its lining was smooth and glistening and thin irregular plaques of calcification were grossly visible in its wall. It was connected by a relatively narrow neck whose lumen was 7 mm. in diameter and whose wall was much thicker than that of the distended sac, with the similar smaller sac which measured  $5 \times 3 \times 2$  cm. Attached to the neck and smaller sac was the mass of vessels which had collapsed to form an irregular small group of vascular channels with dense fibrous supporting tissue. It was at the point



FIG. 4.—Case 2: Photographs of patient (left, one month after operation; right, eight months after operation).

of connection between these vessels and the neck between the large venous sacs that the lesion had ruptured. For this reason careful dissection failed to demonstrate the exact pattern of the lesion. No other communication with the two sacs was demonstrable. Presumably, therefore, they represented enormous saccular dilatations of a huge vein. No definite gross arteriovenous communication could be found.

The microscopic findings will be discussed later.

**COMMENT:** In spite of its great size and potentialities for blood loss, this lesion represents technically the ideal type of angiomatous malformation for radical extirpation, for its arterial supply was superficial (including the unexpected branch of the anterior cerebral artery) and its draining veins converged into a single great channel. Preliminary cortical incision and dissection of the two great venous sacs undoubtedly made rapid removal possible when the moment of rupture came and greatly diminished the cerebral damage which would otherwise have been necessary.

The roentgenologic picture of calcification in this case is by no means typical of the angiomatous lesions and it is difficult to see how a correct diagnosis could have been made preoperatively.

Because of the enormous dilatation and extreme thinness of its walls, this lesion would certainly have ruptured spontaneously sooner or later. For that reason, its removal was a life-saving procedure. Nevertheless, the reappearance of convulsions is a disappointing and tragic sequel to the operation.

**Case 3.**—W. K. (Vanderbilt University Hospital No. 100748), a 29-year-old white farmer, was referred by Dr. Peery Sloan of Jamestown, Tennessee, and was admitted to the Neurosurgical Service January 20, 1943. However, he had first been seen in the Out-patient Department July 25, 1939. At that time he gave a four-year history of convulsive seizures occurring about every eight or nine weeks. There had been no preceding injury or significant injury. The attacks were said to begin with turning of the head to the right, but no other localizing features were recorded. The general physical and neurologic examinations were said to be negative and no abnormality was reported in roentgenograms of the skull. The glucose tolerance curve was normal. The diagnosis was idiopathic epilepsy and the patient was given phenobarbital.

He was not seen again for three years. During the interval, he had very few seizures, only two occurring in the year prior to his return. One month before his return, he had a sudden severe occipital pain which confined him to bed for a week after which it gradually subsided. A similar attack occurred four days prior to his admission to the Medical Service on August 17, 1942. On this occasion he became unconscious for two hours and was found by his local physician to have grossly bloody cerebrospinal fluid. He vomited several times.

On admission, he was drowsy, and complained of severe headache. His neck was stiff and the Kernig's sign was positive. No focal neurologic signs were observed on the Medical Service or by the neurosurgical consultant. The cerebrospinal fluid showed progressively less blood. The red cells and the xanthochromia gradually disappeared, as did the headache and stiffness of the neck. The diagnosis was spontaneous subarachnoid hemorrhage, probably due to aneurysm of the circle of Willis.

On September 5, 1942, pneumo-encephalograms were made and the wet films were interpreted at the time as negative. The ventricular system showed no deformity, displacement or dilatation. Unfortunately, the films were not examined by the neurosurgical consultant until four days later, when the patient had already been discharged from the hospital. This examination revealed faint but definite parallel lines of calcification in the left temporoparietal region with numerous irregular flecks of calcification immediately surrounding. The appearance suggested a mass of blood vessels.

The patient was sent for and finally returned to the Neurosurgical Clinic on October 10, 1942. There had been no symptoms in the interval. A slight right facial weakness and overactivity of the right patellar reflex were observed. He was advised to enter the hospital but did not do so until January 23, 1943.

In the interval, there had been transitory loss of consciousness on several occasions, but no recurrence of his violent headaches.

On admission, the findings were as before, and he also showed distinct weakness of the right upper and lower extremities, and a partial nominal aphasia. There was no dysarthria, disturbance of auditory or visual speech or of handwriting. He was right-handed. Tactile, painful, stereognostic and discriminatory sensations were normal. There was no papilledema. No bruit was audible over the head. Roentgenograms (Fig. 5) showed no change in the intracranial calcification.

Operative attack upon the lesion was advised, primarily because of the probability of recurrence of the spontaneous hemorrhage.

*Operation.*—February 1, 1943: The following is quoted from the operative note:

"Under intratracheal ether, a low left temporoparietal flap was turned down without difficulty. The dura was not particularly tense but there was a bulge extending from the medial end of the incision inferiorly through about the center of the exposed area. This was fluctuant and evidently overlay a very large vessel. Dura was opened widely as usual, disclosing that the bulge had indeed been caused by a huge vein running toward the midline. At its inferior end, it apparently communicated directly with a large artery evidently a continuation of the sylvian artery. The latter was quite tortuous and showed several small visible plaques of calcification. A number of other enlarged vessels, both arteries and veins, converged at the lower border of the flap. However, there were not sufficient vessels to account for the calcification seen in the roentgenogram and also it was recalled that the calcification was largely subcortical. Evidently these vessels were merely the surface connections of a much more extensive underlying angiomatous lesion. A distinct thrill was palpable over the lower portion of the visible tumor.

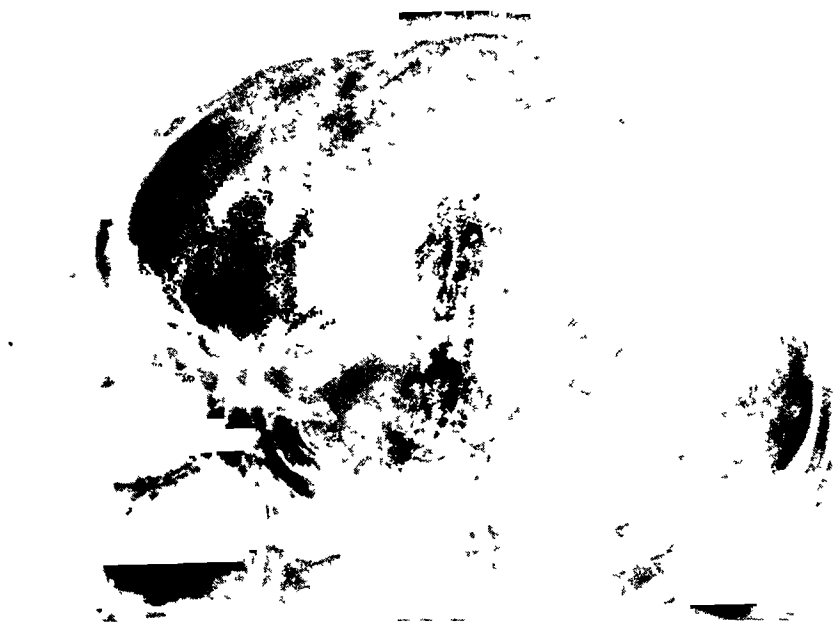


FIG. 5.—Case 3: Roentgenogram showing the faint pattern of lines of calcification indicating a vascular lesion. The calcified area represented only a small part of the total lesion, which weighed 26 Gm.

"I was very hesitant about undertaking the radical removal of this lesion since it seemed almost certain that I should get into serious hemorrhage. However, it was recalled the patient had had two spontaneous hemorrhages and, therefore, that he would almost certainly ultimately have a terminal rupture of the lesion. Therefore, it seemed that any risk was justifiable.

"I first set out attempting to control the entering blood supply. A silk stitch was placed around the large sylvian artery at the antero-inferior border of the flap. This was tied without difficulty and the thrill at once disappeared from the surface. The lesion was then gradually almost encircled by placing silver clips on all of the cortical vessels which led toward the lesion. The large vein leading up toward the midline was not occluded however since I feared that if this was done the lesion might rupture as the result of increased pressure. With the electric knife, an incision was begun on the anterior side of the lesion penetrating the cortex. Large subcortical vessels were encountered but were controlled at this point without difficulty. By blunt dissection this incision was carried down until an area of discolored brain tissue was reached which looked almost

like a neoplasm. I suspect that this was a soft area into which hemorrhage had previously occurred. Inferior to this area a number of large tortuous tangled vessels came into view but I was not yet ready to tackle this deeper portion of the lesion since much of the superficial region still remained. I next tried to place a suture around the sylvian artery distal to the previous ligature. However, the needle evidently entered a deeper vessel and there was vigorous hemorrhage welling up beneath the pia. Something had to be done immediately and I, therefore, tried to coagulate the artery. This caused it to explode and there was violent hemorrhage for a moment. Further attempts at coagulation only made matters worse and the bleeding was finally controlled only by seizing a relatively large mass of tissue in two mosquito clamps. With great difficulty, suture ligatures were placed around these masses and tied down. Thus, the bleeding was finally controlled although I feared it might break out again at any moment.

"Next, the posterior margin of the lesion was attacked in much the same way. That is, the cortex was incised with the electric knife and this incision carried to a greater and greater depth by blunt dissection. The great medial vein had still not been touched. The inferior border was then encircled in the same way and when dissection had reached the depth of three or four centimeters it was apparent that the greater portion of the entering blood supply came from deep in the temporal region in addition to that obtained through the sylvian artery already divided. I proceeded as cautiously as possible to dissect out this entering blood supply from below, but while trying to do this, there was again a sudden violent hemorrhage due undoubtedly to tearing of some thin-walled vessel in the depths of the wound. Again with the greatest difficulty, the bleeding was controlled. During the course of this manipulation, the inferior connections of the angioma had been almost

completely divided and its surface was relatively free. The hard calcified vessels could be easily palpated in addition to a number of large tangled vessels which were not calcified. The lesion was gradually dissected upward but once again another communicating vessel was torn and there was another severe hemorrhage. This was finally controlled by suture ligatures. The lesion was then gradually delivered out of the wound on the hinge of the huge vein extending medially. As this was done, another enormous deep vein appeared but it was secured without much difficulty and coagulated. A suture was then placed around the large medial vein and it was divided, thus, delivering the entire mass in a single piece. After much further difficulty, all bleeding from the clamped tissue below was secured by ligatures and by coagulation and silver clips. The wound was then quite dry. Patient had bled himself into a state of profound shock and was given two large transfusions and a plasma infusion. He rallied to some extent but still had a low pressure and was sweating profusely. Another transfusion was given after the end of the operation. The dura was closed, bone flap replaced and closure carried out in layers with interrupted silk."

*Course.*—As might have been expected following this frightening and extensive procedure, the postoperative course was rather stormy and recovery was slow. The temperature ranged as high as 103° F. for four days then gradually returned to normal. The patient had marked right hemiparesis and almost complete aphasia immediately after



FIG. 6.—Case 3: Photograph of patient 25 days after operation



operation, but these functions also gradually improved. He was alternately drowsy and restless for two weeks, but was able to be out of bed on the 19th postoperative day and was discharged a week later. At this time, (Fig. 6) he understood everything said to him, could carry on simple conversation, but still was unable to name many common objects. He could not read or write. The right hemiparesis was present, but improving as was the right hemihypesthesia. There was astereognosis on the right and he had complete right homonymous hemianopia.

He has been seen regularly. Motor power returned steadily and he was able to return to work on the farm about three months after discharge. Speech functions improved greatly but the visual and sensory defects persisted. Nine months after operation he began to have fleeting "hot flashes" in the right face and upper extremity and these have persisted at varying intervals despite anticonvulsant medication. There have been no major seizures.

*Pathology.*—The specimen removed weighed 26 Gm. and measured  $7 \times 4 \times 15$  cm. It consisted almost entirely of a tangled mass of blood vessels, both arteries and veins, in the walls of which gritty areas of calcification were palpable. Small islands of brain tissue lay between some of the vessels and in one such area, the tissue was dark brown and firm, suggesting old hemorrhage. No definite arteriovenous communication could be demonstrated.

The microscopic pathology will be discussed in the following section.

#### THE PATHOLOGY OF THE ANGIOMATOUS MALFORMATIONS

Space does not permit a lengthy discussion of the mechanism of development of these lesions, a subject summarized by Bailey.<sup>3</sup> Certainly they are congenital. Whether the number of vessels in such a malformation ever increases with the passage of time is controversial, but there can be no doubt that individual vessels in them increase in size by direct distension.

The great variability of the appearance and structure of the vessels of these lesions has led to a complicated and confusing terminology and to numerous attempts at classification. Cushing and Bailey,<sup>1</sup> and Dandy<sup>2</sup> have reviewed the early literature and more recent discussions have been published by Antoni<sup>8</sup> and Ray,<sup>5</sup> Cohen and Kay,<sup>9</sup> Ronne,<sup>10</sup> Northfield,<sup>6</sup> and Bergstrand, Olivecrona and Tonnis.<sup>7</sup> Cushing and Bailey divided the angiomatous malformations into venous and arterial groups. Dandy preferred to include them all under the term "arteriovenous aneurysm." While all must necessarily have a copious arterial supply and an extensive venous drainage, no direct arteriovenous communication is demonstrable in many cases. In none of the three cases herein reported was pulsation of the greatly distended veins visible or palpable. No studies of cardiac output or similar phases of the circulatory physiology have been published.

The vascular anomalies are most common in the distribution of the middle cerebral artery, but may occur anywhere in the cranial chamber. A large and unusual arteriovenous lesion of the base has just been reported by Alpers and Forster.<sup>11</sup>

The occipital lobe angiomas such as that seen in Case 1 seem to have a definite and characteristic pattern which must represent a specific developmental defect, but no clear explanation is yet available. The majority of these occipital lesions have been associated with cutaneous vascular naevi in the

trigeminal area on the same side (Sturge-Weber's disease, Weber-Dimitri syndrome).<sup>9, 10</sup>

The gross appearance of these malformations is extremely variable. Many appear to be composed almost exclusively of tangled, tortuous veins, while others present similar masses of arteries. Cases 1 and 3 represent perhaps the most common type of lesion. In this group, there is an indiscriminate mixture of arteries and veins, rarely with gross arteriovenous communications. Saccular dilatations of individual vessels such as were found in Case 2 are quite uncommon.

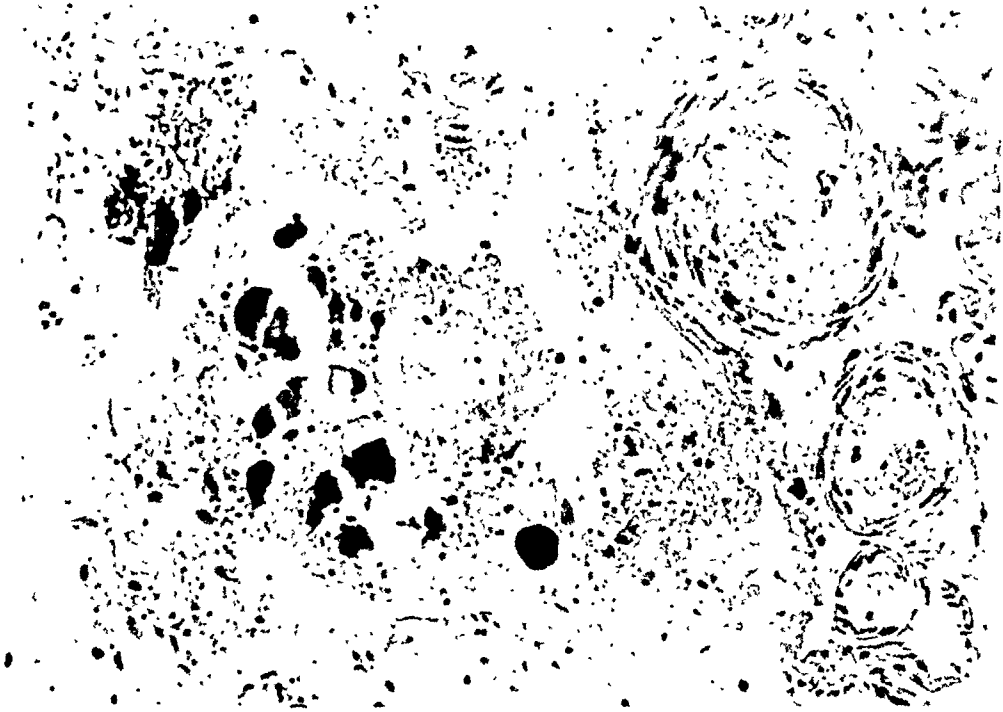


FIG. 7.—Case 2: Photomicrograph of vascular mass, showing area of calcification in the adjacent supporting tissue. (Hematoxylin-eosin. x 120.)

The microscopic appearance of the vascular anomalies is characteristic and quite similar in nearly all cases. The abnormal collections of vessels lie in a matrix of partly degenerated brain tissue in which gliosis and fibrosis are prominent. Often no brain tissue is recognizable in the dense fibrous connective tissue (Figs. 7 and 8). Areas of hemorrhage and degeneration in various stages of organization may be encountered, if leakage has occurred, as in Case 3.

The vessels themselves vary greatly in their size and thickness and this variability appears in different portions of the same vessel as well as in different vessels. The wall of the great venous sac in Case 2 was composed of a thin, stretched fibrous membrane whose fibers were elongated and thin. No intimal or muscular layers could be seen in the sections. On the other hand, in this and the other lesions both arteries and veins of unusual and irregular thickness were seen.

Corresponding to the gross tortuosity there is a characteristic angulation

and infolding of the vessel walls themselves, sometimes resulting in an almost papillomatous appearance.

There is rarely any proliferation of the intima and the muscle is more likely to be thin or missing than thick. The dense elastic tissue, however, is often quite thick, its fibers extremely wavy and sometimes fragmented (Fig. 9).

Calcium may be deposited in the vessel walls but is also found in the supporting connective tissue adjacent to the vessels. In Case 1, almost the whole pattern of calcification seen in the roentgenograms was extravascular, but closely followed the vascular walls in its distribution.



FIG. 8.—Case 3: Photomicrograph showing the vascular pattern and the folded, irregular walls of the vessels. (Hematoxylin-eosin.  $\times 46$ .)

#### DIAGNOSIS

The clinical picture of the angiomatous malformations is variable and dependent upon the location, size and precise nature of the lesion. Nevertheless, the diagnosis can be made in the majority of cases.

Subjectively, convulsions occur in most cases. They may be generalized, as in Case 1, focal, as in Case 2, or equivocal, as in Case 3. The history is likely to be of long duration, and the patient frequently has been thought to have idiopathic epilepsy.

Symptoms of increased intracranial pressure may occur but are unusual. Localizing symptoms, such as paralysis, sensory impairment, aphasia and jacksonian seizures are dependent upon the location and size of the lesion, but no such symptoms may be present at all.

Objectively, the neurologic examination is variable and may be normal. The most common objective finding is intracranial calcification. In most cases,

this calcification is in the form of characteristic vascular markings and is pathognomonic. In others, as in Case 2, it may be bizarre and misleading. The roentgenologic picture of the occipital lobe venous angiomas is recognizable at a glance.<sup>8, 9, 10</sup>

An audible bruit has been heard in relatively few reported cases (and in none of these here reported). When present it is clear proof of a large arterio-venous communication.

The presence of other vascular anomalies and particularly of telangiectatic naevi in the trigeminal distribution is strong presumptive evidence that neurologic symptoms, if present, are also due to a vascular malformation.

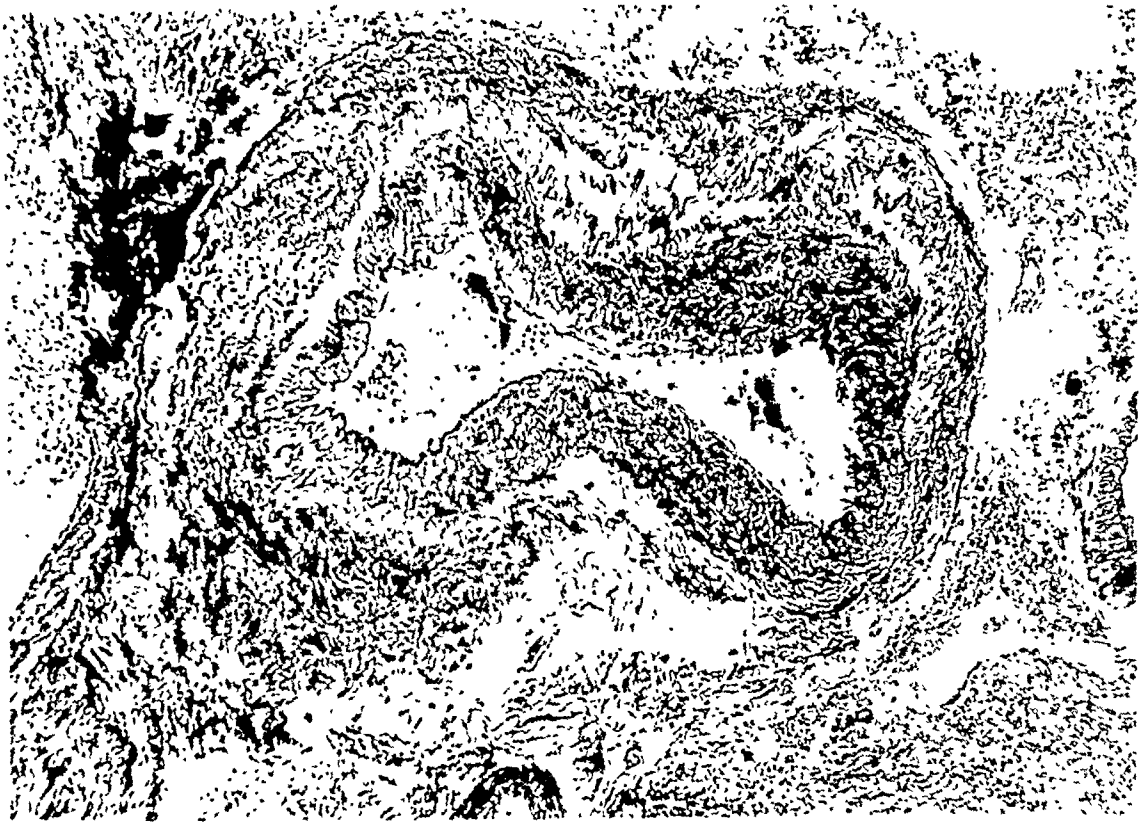


FIG. 9.—Case 3: Photomicrograph of a single artery in the lesion. The wall is angulated. The thick collagenous fibers of the adventitia are fragmented and corrugated. (Mallory's aniline blue-Orange-G.  $\times 120$ .)

Spontaneous rupture or leakage of intracranial vascular anomalies has occurred relatively infrequently, but nevertheless constitutes a constant threat. In Case 3, one and probably two, spontaneous hemorrhages had occurred and, in Case 2, the exceedingly thin walls of the great venous sacs made rupture and fatal hemorrhage an ever-present danger. Bailey<sup>3</sup> records a case of fatal rupture of an angioma and a number of spontaneous hemorrhages from such lesions have been reported. Such a lesion must always be considered as the site of origin of any spontaneous subarachnoid, or subcortical hemorrhage.

In general, the existence of long-standing convulsions in the presence of intracranial calcification which shows a vascular pattern is the soundest basis for the diagnosis of angiomatous malformation, but the neurosurgeon must

be prepared to encounter such lesions in the absence of both of these manifestations.

#### CHOICE OF TREATMENT

To state that all angiomatous malformations of the brain should be radically removed would be foolhardy indeed. Many cause few and mild symptoms, others are bilateral, widespread and obviously inoperable, still others are completely inaccessible.<sup>11</sup> In these three groups, anticonvulsant medication (if convulsions occur) and deep roentgenotherapy should certainly be employed.

There is surprisingly little definite proof of the value of radiation in these cases. Most evidence is based upon clinical impressions and the author is not aware of any pathologic studies upon the subject.

On the other hand, there is considerable reason to believe, upon clinical evidence, that the angiomas which are preponderantly venous will regress in size and in clinical manifestations after radiation therapy. The author has seen two widespread intracranial vascular anomalies and at least three intraspinal lesions of similar type in whom marked improvement occurred (although in two of the latter group, the improvement was only temporary). The mechanism by which such improvement occurs is by no means clear.

Simple palliative subtemporal decompression may sometimes be indicated to preserve vision. It should be employed only when there is marked increase in intracranial pressure and sound reasons for not making a direct attack upon the lesion.

Ligation of the internal carotid artery has also been reported to result in improvement in some cases.<sup>2, 5</sup> This, too, is a purely palliative measure and can only result in temporary diminution in the circulation through the lesion.

In the author's opinion, radical extirpation of a vascular malformation of the brain should be undertaken if the lesion is localized and is the cause of severe and progressive symptoms, such as frequent and uncontrollable convulsions, increasing neurologic deficits or spontaneous hemorrhage.

The three cases reported in this paper illustrate these indications quite well. All had single localized lesions. Case 1 had major convulsions which had occurred at the rate of four or five daily for eight years, and their continuance could surely be expected. Case 2 was operated upon without a definite preoperative diagnosis, but, once exposed, the lesion had to be attacked radically for two reasons: first, because of rapid expansion of the brain, and, secondly, because the thin-walled portion of the lesion was obviously on the verge of rupture. In Case 3, spontaneous hemorrhage, with imminent probability of recurrence, constituted a mandatory indication for radical therapy.

Despite the strong reasons advanced in these cases, the surgeon must decide upon the extirpation of one of these lesions only after profound consideration of all factors involved. Furthermore, he must occasionally have the courage and judgment to withdraw after actual exposure of the lesion.

#### TECHNIC OF RADICAL EXTIRPATION

To propound a uniform plan of attack for all of such a variable group of lesions is obviously impossible. The technical problems have been discussed at

some length in another publication.<sup>12</sup> In this paper, however, a few basic principles are worthy of consideration.

First of all, the surgeon must be aware of and prepared for the special difficulties likely to be encountered. A needle should be in a vein before the procedure is begun and large amounts of whole blood should be instantly available. Silver (or tantalum) clips, fibrin foam<sup>13, 14</sup> or gelatin sponge<sup>15, 16</sup> and thrombin or large amounts of muscle, an electrosurgical unit and a powerful suction apparatus are obvious necessities.

Preliminary ligation of the internal carotid artery has not been employed by the author, but should certainly be considered in some cases.

Once the lesion is exposed, its location, extent and vascular pattern will determine the plan of attack—or, indeed, whether it is to be attacked at all. If it is confined to an occipital or frontal pole, amputation of this portion of the brain is definitely indicated and may be a much simpler procedure than dissection of the lesion. In Case 1, dissection of the occipital lesion was attempted in hope of avoiding production of a visual field defect, but the attempt had to be abandoned and amputation of the lobe carried out. The initial attempt should probably not have been made at all.

Elsewhere in the brain, the surgeon's first attention should be directed toward identifying the principal arterial supply of the lesion and determining whether it can be controlled. If such control is not considered feasible, the operation should, if possible, be abandoned, for uncontrollable hemorrhage is almost a certainty.

If the arterial supply can be isolated, it should be the first object of attack. Under no circumstances should the principal draining veins be occluded until the entering blood supply has been shut off. It must always be remembered that one or more large arteries on the surface may furnish only a portion of the arterial supply. Thus, in Case 2, the supply came from both the middle cerebral and anterior cerebral distributions and, in Case 3, rupture of unexpected deep temporal arteries nearly resulted in fatal bleeding.

Dissection of the lesion itself should begin away from its major venous drainage and, in a sense, the latter should be used as a hinge or pedicle upon which the lesion is gradually delivered. Fortunately, most of the great veins will drain toward the surface and their ultimate control is not usually exceptionally difficult.

Considerable hemorrhage is inevitable even under favorable conditions. It is, therefore, upon the surgeon's ability to proceed rapidly yet with due concern for the control of vessels as they are encountered and for the integrity of the adjacent brain tissue that the patient's life will depend.

#### RESULTS OF RADICAL OPERATION

Cases are too few for any statistical conclusions regarding the safety of extirpation of the angiomatous malformations. Although all three of the cases here reported recovered, a formidable mortality rate must be anticipated in any large series of cases. As already pointed out, however, a large risk may well be justifiable in such cases as these.

From the point of view of end-results, the outcome cannot often be expected to be perfect regardless of the success of the technical procedure. In Case 1, the patient has been completely relieved of convulsions for six years, but she has a permanent homonymous hemianopia. Case 2 has had a recurrence of convulsions but is free of the imminent risk of fatal rupture of the lesion. Similarly, Case 3 has recurrent fleeting paresthetic attacks but will certainly have no more spontaneous hemorrhages, and is seemingly relieved of major convulsive seizures.

## SUMMARY

Three cases in which large angiomatous malformations of the brain were radically removed have been described.

The pathology and diagnosis of such lesions, the indications for their removal and the technic of their radical extirpation have been discussed.

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## AN ANALYSIS OF BRAIN ABSCESES OBSERVED DURING THE PAST THIRTY YEARS\*

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AFTER reading the paper by Pennybacker, published last June in the Proceedings of the Royal Society of Medicine, in which he analyzed a series of 50 cases of brain abscess observed during the past 6.5 years, and because of the very important contribution to this subject made by Clovis Vincent, in 1936, I decided to review our entire experience.

In the past 30 years, 142 cases of brain abscess have been seen in our clinic. In 128 of these 142 patients, the abscess was found at operation, leaving 14 who were operated upon in whom the abscess was not located; of these 14, all except two were seen before the discovery of ventriculography.

Partly because I have followed the principle of operating upon every patient with a brain abscess, regardless of how grave his condition was, our over-all mortality is higher than in other clinics. For example, ten of the 128 patients in this series were unconscious when operated upon, and died within 24 hours. There were others who were in an equally serious condition, but I have arbitrarily called only those patients moribund who died within 24 hours. We have felt justified, however, in operating upon these desperate cases because we have had a few who have recovered, though they seemed moribund.

From time to time, a small series of cases has been reported with astonishing results. All of these cases were encapsulated abscesses. The outstanding series is that of Macewen, who reported 19 cases operated upon with 18 cures; but in that very table, there were six other patients who were not operated upon but who died.

In 1923, Downman reported a series of encapsulated abscesses which had been drained with excellent results, and, in 1930, Coleman reported 26 such cases with four deaths. In this paper, Coleman said: "It is well known that septic encephalitis with formation of small abscess regardless of treatment is practically always fatal." In 1924, and again in 1936, King reported his method of treating such cases, which is known as marsupialization.

In 1935, King made a very important contribution; he described a method of sucking out septic brain material, and said, "This procedure may one day be utilized in certain suitable cases of suppurative encephalitis or phlegmon of the brain in which there is but little tendency to encapsulate." A year later, Vincent reported seven cases treated in this way, with six cures.

There are many cases of brain abscess which do not belong to what is generally conceded to be the favorable type—the encapsulated abscesses—and these unfavorable ones are the ones we must learn to treat more effectively. In fact,

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the prime purpose of this review is to consider the care of those cases hitherto thought almost hopeless.

In analyzing our series, I have excluded only one group—the abscesses secondary to pulmonary infection. Both Pennybacker and we have had uniformly bad results in this group. The mortality has been almost 100 per cent. Pennybacker lost 11 out of 12 patients, and we lost 19 out of 20. These bad results are due, I believe, first, to the prolonged and debilitating illness these patients have had; and second, and even more important, to the type of organism which is responsible—an anaerobe which is not found in other brain abscesses. Patients with this type of organism have had huge abscesses before they showed any symptoms. The first warning of any intracranial involvement has usually been a convulsion followed by unconsciousness or coma. Very few of our patients presented any signs of pressure, and only three had choked disk.

Excluding this group, we have 108 cases to consider, and I have not attempted to classify them either according to etiology or location, because I believe that the outcome depends primarily upon the treatment. As stated above, we have operated upon all cases of brain abscess, no matter how grave their condition.

TABLE I

BRAIN ABSCESS—128 CASES

Cerebral, 97 (moribund, 9)	Drained	40	11 cured
	Aspirated	38	15 cured
	Marsupialized	11	9 cured
	Marsupialized and excised	2	2 cured
	Excised	6	6 cured
Cerebellar, 11 (moribund, 1)	Aspirated	9	5 cured
	Drained	2	0 cured
Abscesses secondary to lung suppuration		20	1 cured

In our clinic, aspiration of cerebral abscesses has been somewhat more successful than drainage, but the mortality with both methods has been high. In reviewing the 52 deaths in this series, it is now clear that we used to aspirate cases repeatedly, even after a capsule was well formed, and drained others in whom a capsule had not yet formed. In the last few years, I have become more and more convinced of two things; one is that aspiration should be used only until a capsule has formed, and that the abscess should then be excised, and the other is that the only time drainage should be used is when the abscess has ruptured in the course of excision and, therefore, has to be marsupialized. This is the policy which we have been following during the last three years. Of 18 cases in that period, 11 recovered. All were marsupialized or excised. Of the seven who died, one was moribund, one had been home for more than six months and was apparently well when she suddenly died, presumably from another abscess. Three had meningitis in addition to an abscess at the time of admission, and the seventh case was aspirated three times in the hope that a capsule would form. In this last instance, the abscess should have been sucked out at the time of the first aspiration.

In patients with cerebellar abscesses, the only ones who recovered were

those in whom the abscess had been aspirated. We have never attempted to excise a cerebellar abscess, and I have found no record, either in Pennybacker's or Vincent's reports, where this was done.

Whenever possible, it is desirable to postpone excising an abscess until it has become encapsulated, and undoubtedly penicillin has helped materially in tiding patients over the acute stage and giving the infection time to become walled-off. Furlow has recently reported six cases from the Naval Hospital in San Diego in whom, with the use of penicillin, the infection became localized and encapsulated.

In 1927, I first treated two patients by marsupialization, and, in 1929, treated a third by excision of the abscess. All three of these patients recovered, but I did not realize at that time that this was the method which we must attempt to employ in all cases of cerebral abscess.

In order to get patients in condition for this procedure, they must be treated with penicillin while in the acute stage, aspirated, sometimes several times, and, thus, tided over, if possible, until the abscess is ready to be excised. Vincent advocates what he calls a decompression during this period of waiting. By that he means removing the bone over the region of the abscess but not opening the dura. We have not done this. I have never felt that removing bone had any decompressing effect. Pennybacker had made use of this procedure occasionally, but feels that, as a rule, repeated aspiration will tide the patient over until a capsule forms. I do not feel as optimistic about this as Pennybacker, because we had ten cases in our series who died within 24 hours after the first aspiration so that there was no chance for a capsule to form, and I doubt whether penicillin therapy could have changed the outcome. However, that is certainly the procedure to follow, namely, to give large doses of penicillin to patients with acute abscesses, aspirate them in order to tide the patient over the acute stage, then excise the abscess completely and remove by suction all brain tissue that shows any sign of encephalitis.

In the 19 cases in our series which were marsupialized or excised, five had acute abscesses, and these were sucked out and treated, as suggested by King and Vincent. In some of the marsupialized cases, much of the capsule was excised, but as it was impossible to remove all of it, these cases were drained. The six excised cases were sewed up tightly, and had primary unions.

#### CONCLUSIONS

To sum up, we have reached the following conclusions:

1. No unencapsulated abscess should be drained.
2. During the acute stage, penicillin is an invaluable aid in bringing about encapsulation.
3. Aspiration, except in cerebellar cases, should be used only as a palliative procedure until more radical treatment can be instituted.
4. Excision without drainage is the ideal procedure, but frequently marsupialization must be resorted to if, in the course of an excision, the abscess has been ruptured.

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# CRANIOTOMY AND TOTAL DISSECTION AS A METHOD IN THE TREATMENT OF ABSCESS OF THE BRAIN\*

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THERE are no recorded experiences in the literature where a purposely planned surgical attack has been made to completely resect every gross vestige of a demarcated abscess located within the brain tissues. The idea of total extirpation of such an abscess is not a new concept. Such reports refer only to those experiences in which the abscess has been removed *in toto*.<sup>1, 2, 3</sup> The recoveries in these cases have been ideal. Where a rupture occurred,<sup>4</sup> or there was wound contamination, the serious complications, sequelae or protracted hospitalization, as have happened with all other of the numerous surgical methods in treating brain abscesses, have followed. The few experiences to be cited here suggest that when intact removal is impossible that complete dissection with the patient fortified<sup>5-8</sup> against an infectious-spread may be a better method than incision and drainage, simple aspiration or marsupialization efforts. It is physically obvious that dissection efforts in a "diffuse infective encephalitis" or "a pus-containing cavity with ragged wall consisting of softened brain tissue" (Sargent<sup>1</sup>) would not be considered as suitable cases. For these, systemic treatment and the recent experiences of Furlow,<sup>8</sup> using penicillin, offers an optimistic hope that in the future better results may be accomplished in these cases than has been accomplished in the past. The author, as has almost every other neurologic surgeon, has had the rare experience of removing a "brain tumor" *in toto*, to learn later that the central cavity of the very thick-walled granuloma contained bacterially active pus. Again, the treatment of these, although fundamentally it does not differ, is not within the scope of this communication and is purposely omitted. Before the introduction of the sulfa derivatives and penicillin, the opening of a pus-containing lesion at the time of a craniotomy immediately brought forth the fears of a meningitis, prompted immediate drainage and, if a postoperative fatality was escaped, it usually meant a subsequent sacrifice of the osteoplastic flap, rather likely a cerebral fungus formation, and a prolonged hospitalization necessitating daily care and constant attention. Although the first case in this series was prompted somewhat by virtue of a necessity, the other four have reacted so favorably it is proposed to add subsequent cases in order that an accurate evaluation and comparison with other methods of treatment may be accomplished.

## CASE REPORTS AND COMMENTS

**Case 1.**—A boy, age 4, was taken ill with bilateral earache on December 10, 1941. Three days later the left drum was incised and sulfathiazole by mouth begun. There was no aural drainage. On December 17, he developed pneumonia, and the left ear began to

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drain pus. The pneumonia rapidly cleared. On December 20, a diagnosis of mastoiditis was made; this diagnosis was confirmed at operation two days later. He was discharged from the hospital on December 30, apparently well.

February 7, 1942: His mastoid wound had healed and he had no complaints. The following day he complained of headache and the day after this he had an associated forceful vomiting accompanying the progressive headaches. On February 10, a motor aphasia developed, and within 24 hours a complete right hemiplegia was present. On February 12, a left temporal abscess was aspirated; three days later tube drainage was instituted.



FIG. 1.—Showing the previous trephine skull defect through which the thorium dioxide was injected into the abscess cavity. This media only permitted visualization of the most superficial cavity.

The neurologic symptoms rapidly disappeared and by April 1 the wound had healed and the child again was discharged from the hospital. Ten days later all the neurologic symptoms recurred and, again, on April 17, tube drainage was instituted, but this time the aphasia, hemiplegia and projectile vomiting failed to clear. The attending neurosurgeon was called to military duty and the child was referred for further neurosurgical evaluation. With each reappearance of symptoms or temperature elevation this child was given sulfathiazole.

*Physical Examination.*—April 27, 1942: The patient was a lethargic, emaciated, acutely ill, unresponsive child. There was a bulging defect in the posterior temporal area on the left, with an encrusted scab in the center of a 1.5-inch surgical scar. This elevation was soft to palpation but exhibited no free pulsations. There was a bilateral choking of both optic nerves. Right hemiparesis was demonstrable. No conversation could be elicited from the child.

*Aspiration and Thorium Injection.*—April 29, 1942: The old left temporal scalp scar was excised. An abscess was entered with a ventricular needle less than 1 cm. from the dural level; approximately 60 cc. of pus was aspirated and 10 cc. of thorium dioxide was injected into the abscess cavity. Culture of the pus resulted in a growth of influenza bacilli.

*Treatment and Progress.*—Sulfadiazine by mouth was administered daily, and a blood level of 9.8 mg. was maintained. Three days after aspiration drainage, speech had returned and the right hemiparesis was disappearing. On May 5, the spinal fluid pressure was over 300 mm. of water and the fluid contained 27 cells per cubic centimeter. The thorotrast shadow, which, on April 29, was visualized as a cortical shadow in the middle portion of the temporal lobe, had shifted, by May 4, to a more posterior position and nearer to the midline (Fig. 1). The bulging scalp became more tense and the herniation increased the scalp elevation.

*Craniotomy-Dissection of Multilobular Abscess.*—May 9, 1942: The former wound was transformed into an enlarged hockey-stick scalp incision. The original trephine opening was enlarged with the bone rongeurs to a diameter of 5 cm., exposing the posterior midparietal, the anterior midoccipital and the superior posterior temporal lobes. The gangrenous edematous cerebral fungus was sacrificed with the cautery. The abscess stalk was a part of the cerebral fungus, so that an abscess cavity was immediately entered. This abscess cavity harbored an ounce of pus, and when this had been thoroughly and repeatedly irrigated and its location thoroughly established, this cavity did not correspond to the thorotrast outline on the roentgenogram of May 4. A small dural flap was then turned down and an exploratory needle introduced in a new area superior to the exposed cavity. At a 2.5-cm. depth a new resistance was encountered. The initial abscess capsule was then dissected from out of the white matter and in its superior as well as posterior limits a dumb-bell effect was encountered. Each of these continuities with the surfaced capsule broke into separate abscess cavities, each being as large as the first. As the pus was removed by suction, dissection of the respective capsules was carried out by traction on these capsule walls with cotton pledget stripping of the adjacent white matter. The removal of this triple-lobed abscess left a remaining hemispheric cavity that extended well forward under the parietal area, almost to the left occipital pole and into the major posterior two-thirds of the left temporal lobe. With such a sacrifice of underlying tissue a complete closure of the dura, including the original trephine defect, was easily accomplished. The scalp was sutured in the usual two-layer manner without drainage.

*Bacteriology.*—Gram-negative diplobacillus. Culture: *Bacillus influenzae*.

*Postoperative Course.*—The child's condition on leaving the operating room was extremely critical, although intravenous fluids and citrated blood had been administered throughout the procedure. Following a third transfusion the recovery from shock was satisfactory. Continuous intravenous Hartman's solution was maintained for three days. Sulfapyridine intravenously was administered (3 grains per pound body weight) daily for three days. On the seventh day after operation the child was able to take food, fluids and medicines orally. A blood level of sulfa, never below 21 mg., was maintained until May 27, a total of 18 days. On May 21, the lower end of the scalp wound began to bulge and a spontaneous rupture, with an abundance of purulent drainage, occurred. A drainage tube was easily inserted beneath the scalp. Into this tube a continuous drip of five per cent sulfanilamide solution was maintained. The tube was forced out of its subscalpular position by June 4, following which, complete granulation healing occurred. The child was discharged from the hospital on June 13, with normal speech, a right homonymous hemianopsia and a partial right hemiplegia. The paralysis had cleared by August, 1942, and the child has remained well since hospital dismissal. The illness, including the period of treatment extended over a period of 184 days.

COMMENT.—The problem which this patient presented was that the more orthodox neurosurgical procedures had been unsuccessful and, if a cure was to be effected, more radical efforts would be necessary. The lesion as outlined

by the thorium dioxide<sup>9</sup> was visualized as being more posterior and considerably larger than the skull defect, so a larger bony exposure, with cortical uncapping to allow the lesion to "surface," was initially considered. With the hope that the preoperative fortification with sulfapyridine might prevent a meningitis or a spreading encephalitis, it was decided to extend the trephine opening to craniotomy-size and perform a total dissection of the lesion. The consistency of the capsule had been estimated from the duration of the illness and confirmed at the time of the injection of the contrast media. In the process of removing the overlying edematous cerebral cortex, the stalk of the abscess

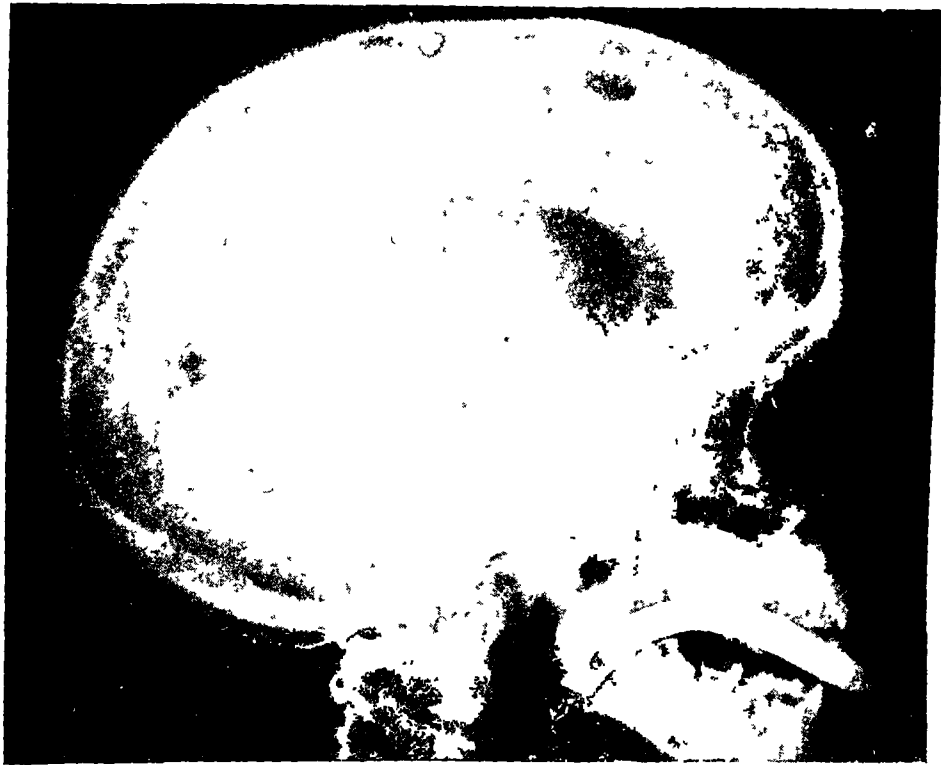


FIG. 2.—The right hemiparesis and the absence of any cerebellar objective symptoms suggested a left temporoparietal abscess. The acquired symmetrical internal hydrocephalus outlined by ventriculography excluded this clinical location.

was opened with the cautery and the pus evacuated by suction. Although the capsule had been extremely resistant to the ventricular needle puncture, the wall proper was rather friable, so that its removal was somewhat in piecemeal. The cavity was entirely medullary white brain matter except for a small raw 1.5-cm. mass on its mesial wall. This was very firm to palpation and when punctured with an aspirating needle 20 cc. of pus was drawn into the attached syringe. This cavity was entered after the exposed projection had been opened (1 cm. core) with the cautery. It was possible to hold this capsule with the pituitary cup-forceps and dissect the entire sac except for what appeared to be a posterior attachment. This attachment was severed and the delivered capsule had 3-cm. openings on both ends. The "attachment" remaining proved to be a third cavitation of pus and when this had been opened, its contents

removed by suction and dissected free from the brain, there remained only a brain cavity surrounded entirely by the white matter.

The failure of the orthodox efforts might well be explained on the multilocular character of the abscess. The thorium visualization demonstrated the presence of but a single abscess and that one the most superficial. The initial aspiration (February 12, 1942) did improve the child's general condition but free drainage was necessary before any neurologic improvement occurred. It was reported that the amount of pus recovered at the time of the insertion of the first drainage tube was comparable to that amount which was aspirated 70 hours previously. The surgical efforts instigated prior to the radical dissection illustrate the long tedious difficulties that every one has had, at least once, in any worth while series of abscess experiences. The total period of illness to date of hospital discharge in this case was 184 days. The hospitalization of the radical abscess removal was 37 days.

**Case 2.**—A 12-year-old girl was taken ill, in April, 1942, with a complaint of bilateral earache. The left ear promptly began draining. Two weeks later mastoid pain on the left side appeared and the child's temperature became elevated above the normal. She was then given sulfa medication orally. Her temperature returned to normal after three days, but she began to complain of frontal headaches and there occurred early morning projectile vomiting. A spinal puncture was performed followed by symptomatic relief. On June 14, the headache and vomiting returned; the child complained of a photophobia and a diplopia. A brain abscess was suspected, and the child was referred for neurosurgical study.

*Physical Examination.*—June 21, 1942: The patient was a lethargic, listless child, whose physical appearance was very good. She consistently lay on her right side, shielding her eyes from the light. Neck flexion offered some pathologic resistance. Both optic nerve heads were swollen to four diopters elevation. There was a left external rectus palsy. There was a right facial weakness. The left arm and leg were more facile than the right extremities. All the deep reflexes were hyperactive. Roentgenograms of the skull were only pathologic for a left mastoid disease "with destruction of the left petrosal cells."

*Ventriculogram—Aspiration of Abscess.*—June 24, 1942: Frontally performed ventricle air injection outlined an acquired internal hydrocephalus of all the supratentorial cavities (Fig. 2). Following the ventriculogram the left occipital bone was trephined and a left cerebellar abscess was aspirated of 40 cc. of pus. Ten cubic centimeters of sulfanilamide solution was injected into the abscess cavity before the aspirating needle was removed.

*Bacteriology.*—Gram-positive coccus. Culture: Type-III pneumococcus.

*Mastoidectomy.*—June 30, 1945: Dr. Lester Brown performed a radical mastoid operation. Free pus was encountered when the petrosal tip was unroofed. The recovery from this was effective but the intracranial symptoms continued in a progressive manner.

*Cerebellar Craniotomy—Dissection of Abscess.*—July 17, 1942: A left unilateral suboccipital scalp flap was hinged inferiorly. The previous trephine opening was enlarged to a bone sacrifice of the entire left occipitocerebellar skull. The dura was reflected. A cerebellar cortical sacrifice of 2.5 cm. was made from the "stalk" of the previous aspiration site. The abscess was opened and its contents, of some 40 cc. of thickened pus, removed, by suction. Grasping the friable capsule with the cupped tissue forceps, folding it into the cavity made possible by the uncapping and aspiration, the mass was easily stripped from its engulfing cerebellar substance. This was accomplished by cotton pledget wedging dissection. The tip of the abscess, when removed, permitted identification of both the fifth and sixth cranial nerves. Three grams of sulfanilamide crystals were powdered into the remaining cerebellar cavity, the dura was resutured and the scalp closed in



layers without drainage. A 250 cc. citrate transfusion was administered, and the child left the operating theater in good physical condition.

*Postoperative Course and Treatment.*—There was a comfortable, gratifying convalescence. Sulfapyridine in three grain dosage per pound body weight per 24 hours, was begun on the first postoperative day and was continued for a total of 16 days. Free pulsations continued in the operative area throughout the remaining hospitalization. The mastoid wound had healed by August 1, and, on August 7, her neurologic symptoms and findings had disappeared. On this date she was discharged from the hospital, and she has remained well (Fig. 3).

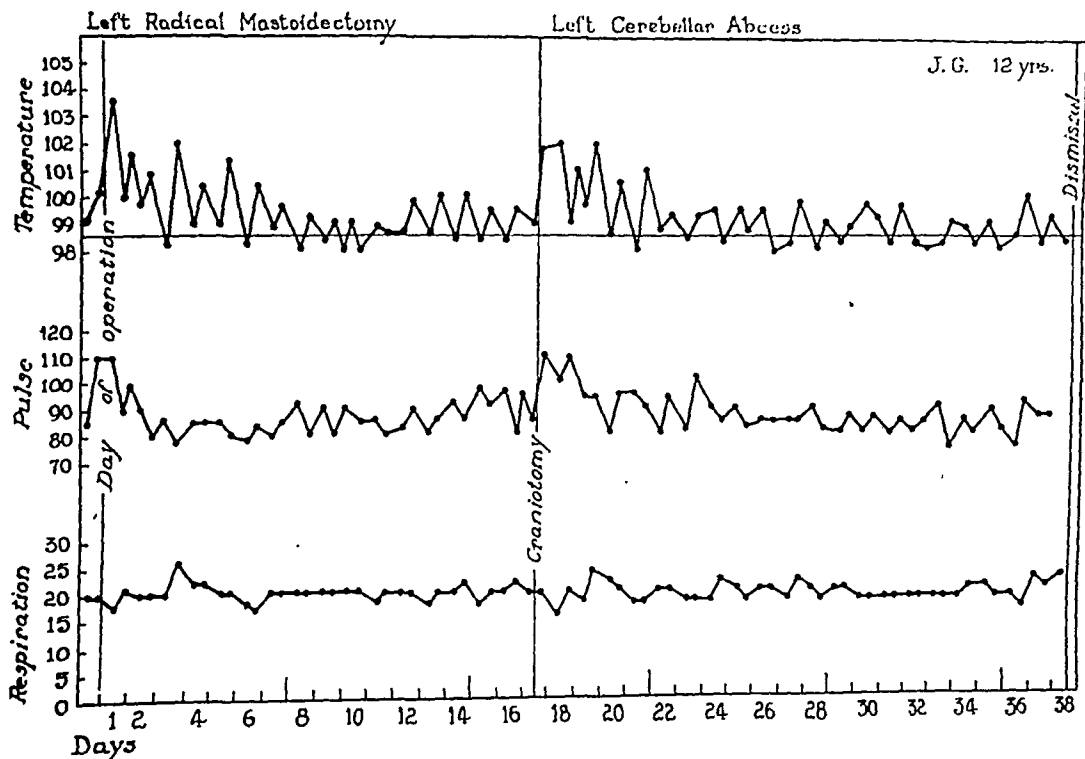


FIG. 3.—The clinical chart of the entire hospital period in Case 2.

COMMENT.—The increased intracranial pressure in this patient presented the most serious problem, so that following pneumoventricular localization, aspiration of the abscess appeared wiser in anticipating the radical mastoidectomy. This one fundamental in the treatment of brain abscesses is so important that a deviation from the purpose of this communication seems justifiable. Unless the focus of the abscess is abolished before, or at the time the brain abscess is treated, a cure may not be effected. A recurrence of the abscess is to be expected and, when the focus is within the bony structures, osteomyelitic processes are likely to develop. The aspiration in this case permitted an omission of any emergency efforts, and allowed effective convalescence from the petrosal infection. Further, it was demonstrated at the time of the craniotomy that in this particular case aspiration alone would not have been adequate treatment for a cure. Forty cubic centimeters of pus was removed at that time. Twenty-three days later, at the time of the craniotomy, an equal amount of pus was removed when the abscess cavity was opened. Both specimens con-

tained Type-III pneumococci. It is to be recalled that sulfanilamide had been injected into the abscess at the time of aspiration. The local application of sulfanilamide, undoubtedly, prevented an encephalitic-meningitic process, and allowed primary wound healing. The systemic sulfa therapy unquestionably complemented this topical treatment in obviating these infectious complications.

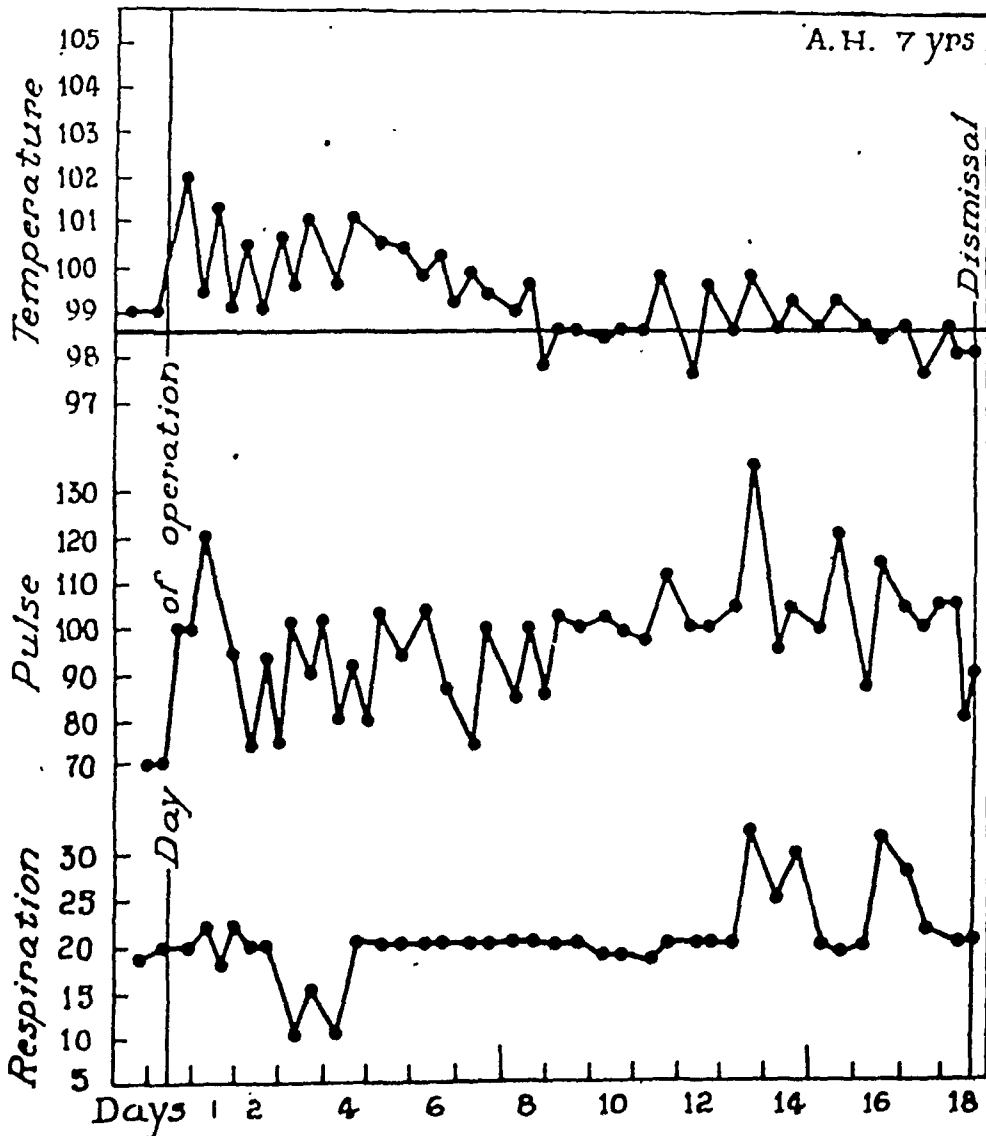


FIG. 4.—Convalescence was unmarred, and the patient was permitted to be out of bed on the 13th postoperative day.

**Case 3.**—A seven-year-old girl had the onset of her illness on December 18, 1943 with influenza. She was ill for four days and then began to have headaches. This was subsequently associated with a postural type of vertigo. She then developed generalized weakness and became rather listless, and there occurred a handicap in the use of her right arm and leg. Although she was normally right-handed she "preferred to use her left hand." January 25, an associated vomiting attended her more severe headaches.

**Physical Examination.**—February 4, 1944: Temperature 99.3°F. Pulse 110. She was very fretful and uncoöperative. Physical development was very good. Bilateral choked disks and motor weakness of right arm and leg were noted. The abdominal reflex was absent on the right. There was generalized hyporeflexia without demonstrable pathologic reflexes. The right ear drum was injected and there was a tenderness over the right mastoid tip. Roentgenograms of the skull and mastoids were normal.

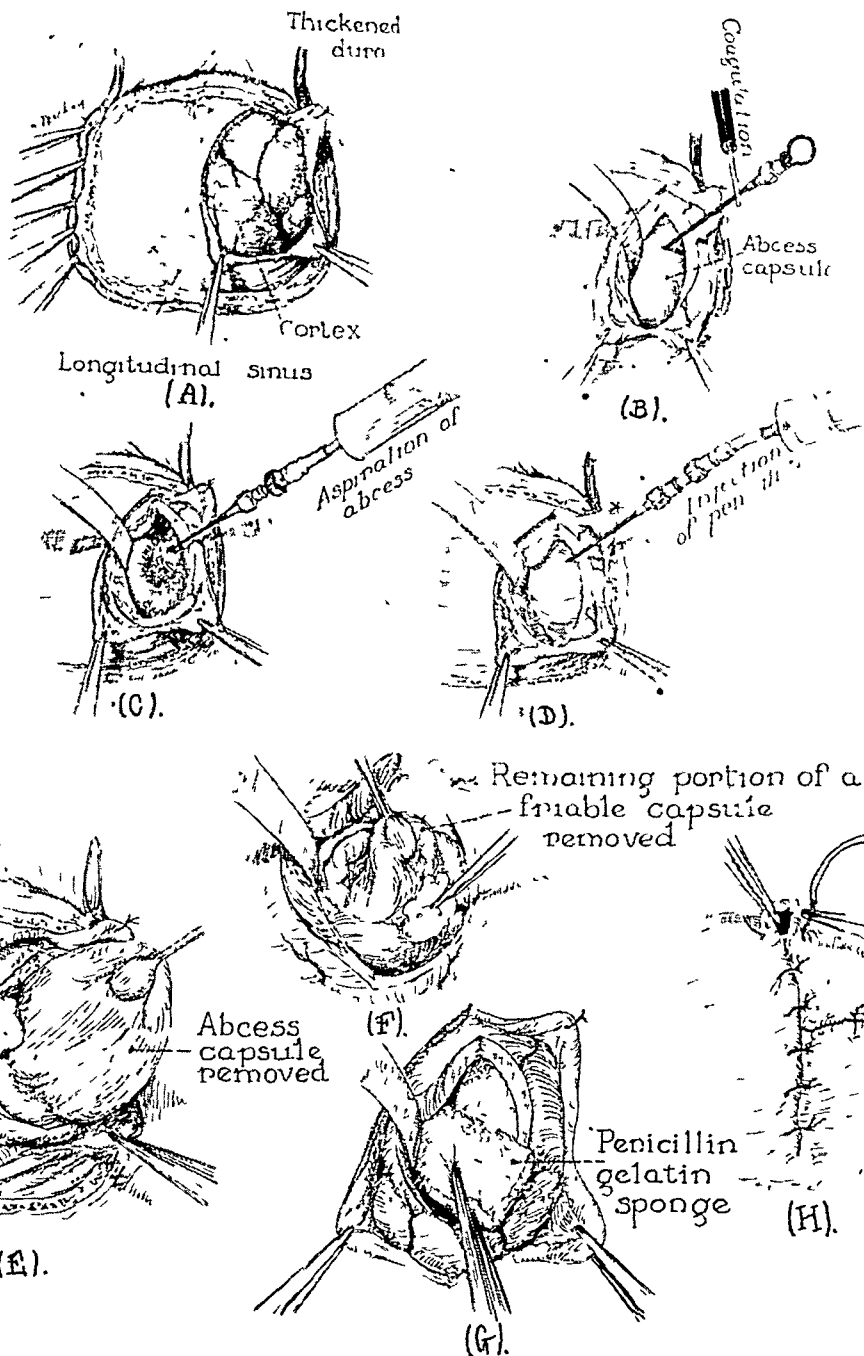


FIG. 5.—A. When the cortex has been exposed the depth of the abscess is determined by the exploratory ventricular needle.

B. The overlying cortex may be transected or a circumcisional uncapping performed to give an adequate exposure of the dome of the abscess. The exposed cortex and medullary brain are protected with cottonoid strips soaked in penicillin. The abscess is punctured under electrocoagulation.

C. Syringe aspiration of the cavity for gaining space for capsule dissection and for specimen collection minimizes wound contamination as compared with open suction methods.

D. The total amount of penicillin solution injected is for less than the volume of pus aspirated. The needle is withdrawn under electrocoagulation.

E. The small opening made by the aspirating needle is closed with the cupped forceps and, if possible, this traction-hold is maintained throughout the capsular dissection.

F. The friability of the abscess wall or the size of the lesion may necessitate piecemeal dissection. This is accomplished best with cotton pledget dissection, folding the abscess wall into its own cavity.

G. Gelatin sponge strips soaked in thrombin and then penicillin are placed in the medullary cavity. They are useful in sealing an opening into the ventricle cavity should such an accident occur in the dissection.

H. The dura is sutured tightly as in routine craniotomy following a tumor removal.

*Ventriculogram.*—February 4, 1944: Frontally performed ventricular air injection outlined a symmetrical dilation of all of the ventricular cavities above the tentorium.

*Cerebellar Craniotomy—Dissection of Abscess.*—February 4, 1944: Through a cross-bow exposure the cerebellum and first cervical spinal cord level was exposed. The right cerebellar lobe was full and the lamellae broadened. An exploratory needle introduced into this hemisphere encountered a resistance 1.5 cm. from the cortex surface. This resistance was that of a tennis ball. A split was made in the cortex and the surface of a soft demarcated mass was inspected. The upper outer one-third of the cerebellar cortex was then sacrificed, exposing a domed mass for an area of 2.5 cm. A ventricular needle was introduced into the cavity of the mass with the aid of electrocoagulation. As the stylet

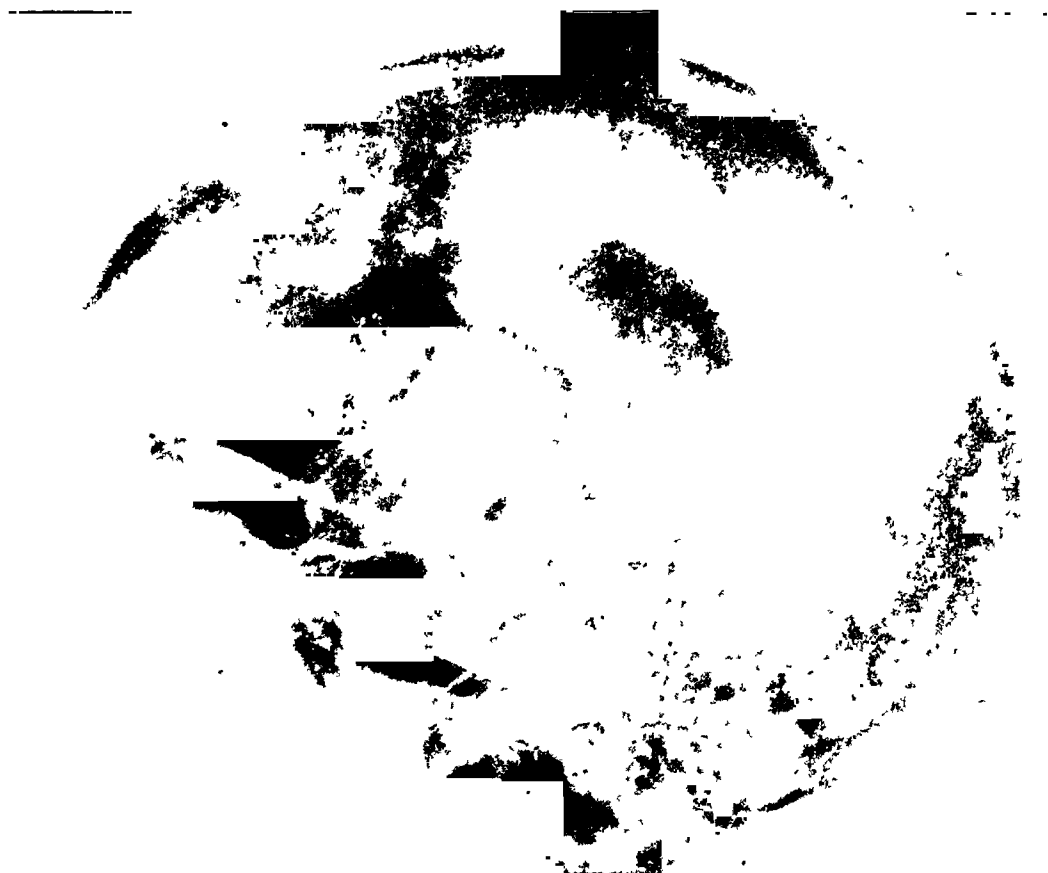


FIG. 6.—The clear-cut ventricular deformity of the right cavity suggested a demarcated rather than an infiltrating lesion as was clinically suspected.

from the needle was withdrawn, syringe suction was immediately applied to the end of the needle and no free pus allowed to soil the exposed field. After a collapse of the abscess from suction, the opening was closed with the pituitary cup-forceps, and this hold on the abscess capsule gently maintained throughout the dissection. With cotton pledget wedging dissection the adjacent cerebellar substance was detached from the pathologic lesion. To gain room for the continued dissecting process it was necessary to reinsert the aspirating needle through the original puncture wound as it was necessary to aspirate the pus on two subsequent efforts. The final dural attachment of the capsule was at the petrosal dura. A four-centimeter cavitation was left when the entire abscess wall had been removed. Two grams of sulfanilamide was sprinkled into the bottom of the cavity and an additional 25,000 units of penicillin was injected into the same area. The dura was closed tightly, as were the muscle layers, deep and subcutaneous fasciae. Two hundred and fifty cubic centimeters of citrated blood was given intravenously, and the child's condition was most satisfactory upon completion of the operation.

**Bacteriology.**—A gram-positive coccus. Culture: *Streptococcus viridans*.

**Postoperative Course and Treatment.**—Sodium sulfadiazine in normal saline (2.5 gm. in 500 cc.) was administered intravenously each day for three days. She was then given one gram of sulfadiazine by mouth every four hours for the ensuing ten days. The skin sutures were removed after 96 hours. She was out of bed, walking, with no handicaps, on February 20, and was discharged from the hospital on the 22nd, after a total of 22 days hospitalization (Fig. 4). She has remained well.

**COMMENT.**—This case illustrates the technical maneuvers that were utilized in this and the subsequent two cases (Fig. 5). Completely, to uncap an underlying abscess for an area equal to the greatest diameter of an abscess would always require a sacrifice of a very large area of overlying brain tissue, but by exposing the dome of the abscess (in this case a 2.5-cm. sacrifice) adequate room for aspiration, for grasping the capsule and for dissection is available. The surrounding brain tissue is walled-off with penicillin-soaked cottonoid strips, the distal ends of which are gently inserted between the abscess wall and the adjacent medullary brain tissues. A 3-mm. spot is coagulated on the dome of the abscess and, with the aid of electrocoagulating current, the abscess cavity is punctured with the ventricular needle. Allowing no free pus to spill into the wound, aspiration of the cavity for its full contents is accomplished by syringe suction. This fluid collection is for bacteriologic studies and for a measurable estimate of the size of the cavity. Without removing the needle, once the cavity has been emptied, penicillin is injected into the cavity, the stylet of the needle reinserted and the needle withdrawn under electrocoagulation just in the manner that it is inserted. The needle opening is closed by grasping the now flabby capsule with the cupped tissue forceps. It is desirable that this hold be maintained, but tissue age does not always permit this. If an uncapping of the cavity is done, owing to the friability of the abscess wall, the cup-forceps still remain effective in allowing mild traction on the abscess wall. This is accomplished by having one cup inside the cavity and one outside. With this traction, placing the cottonoid strips deeper as cotton pledget dissection forces the surrounding white matter away from the abscess wall, one encounters no hemorrhage from this bed. Once beneath the greater diameter of the abscess one finds the strips and the intracranial pressure delivering the sac or its final remnants to the surface. Gelatin sponge strips are placed in the rapidly narrowing remaining cavity. The technicalities, from here on, are those of any clean craniotomy, namely, tight closure of the dura, suturing of the osteoplastic flap and layer closure of the scalp without drainage.

**Case 4.**—A 47-year-old farmer dated the onset of his sickness from January, 1945, at which time a diagnosis of malaria was made. This illness consisted of one chill and one temperature elevation, and the treatment consisted "of three days of sulfa drugs." In February, early morning headaches developed. These were frontal in location, a bit more severe on the right side and infrequently associated with vomiting. Soon after the onset of headaches, he began to stagger, and usually to the left side. There followed a photophobia, a diplopia and a failing memory for recent events.

**Physical Examination.**—April 30, 1945: The patient was a coöperative, fairly alert adult. Both optic nerves were elevated some three diopters. There was a left facial weakness of central type. There was an incoordination in the use of the left arm and leg.

There was a left homonomous visual field defect. Routine roentgenograms of the skull were only significant in that the pineal calcification was shifted to the left.

*Ventriculogram.*—May 3, 1945: Frontally performed ventricle air injection depicted a space-occupying lesion in the right posterior temporal area (Fig. 6).

*Right Temporal Craniotomy.*—May 3, 1945: Through a left temporal osteoplastic flap the volume of the right temporal lobe was exposed. The intracranial pressure was so increased that no free cerebral pulsations were visible or palpable. An exploratory cannula was introduced into the brain substance in the posterior part of the midtemporal convolution and a characteristic resistance was encountered 2 cm. from the cortex surface. With electrocoagulation this resistance was punctured and the stylet of the cannula was removed. Two ounces of pus was aspirated. Penicillin (100,000 units) was injected into the abscess and again with electrocoagulation the cannula removed. Free cerebral pulsations were thus



FIG. 7.—The specimens photographed on a centimeter-squared background show the elliptical "cortex cap," A, which sacrifice was necessary to expose the dome of the large abscess, B.

established and the dura was reflected for the area of its exposure. The midtemporal convolution was broadened and pale. A 3-cm. circumsion (Fig. 7A) was made about this convolution and at a depth of 2 cm. in the white matter the smooth dome of the granulation mass was displayed. With cotton pledget-wedging maneuvers the capsule was caught with the cupped forceps. It was too friable for worth while traction so that the dome was excised with the electric current. By folding the walls of the abscess into its own cavitation and with gentle retraction, complete freeing of the base was permitted (Fig. 7B). During this dissection, on the mesial surface of the abscess, a small opening was made into the lateral ventricle. The bleeding from the surrounding medullary brain substance was indeed minimal. Three grams of sulfanilamide crystals was sprinkled into the bed of the intracerebral cavity. Gelatin sponge strips soaked in penicillin were placed in the bed of this cavity and along its walls. The dura was sutured tightly. Two grams of sulfanilamide were placed outside the dura, the bone flap sutured *in situ* and the scalp closed without drainage.

*Bacteriology.*—Culture: *Staphylococcus aureus*.

*Postoperative Course and Treatment.*—The convalescence was not marred by any disturbing upsets. Penicillin (25,000 units) was administered intrathecally every other day for five doses. Intramuscular penicillin was administered every three hours for six days. The highest cell count in the spinal fluid was 509 cells per cubic centimeter from five

studies, and no organisms were cultured from any of these specimens. The patient was permitted out of bed on the 11th day after operation, and discharged, May 21, after a total of 21 days hospitalization. Seen on September 28, the patient was feeling "quite normal," there were no residual palsies, but there was a complete left homonymous hemianopsia.

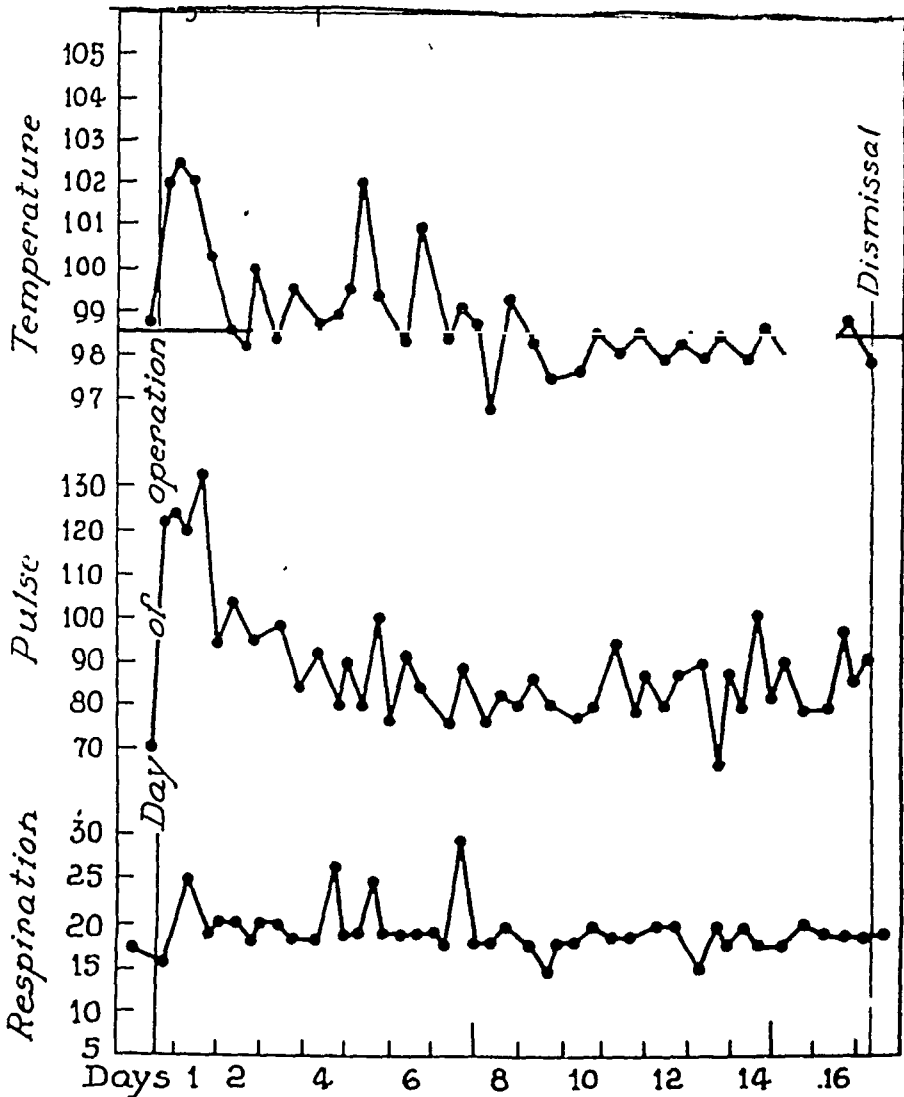


FIG. 8.—This clinical chart could be substituted for any normal convalescent craniotomy in which a benign tumor might have been removed.

COMMENT.—The infectious history in this case was obtained after the pathologic diagnosis had been made. He was considered clinically as a right temporal lobe tumor and, on account of the short history, an histologic diagnosis that his "tumor" was a glioblastoma was made. The ventriculographic depiction was more that of a "demarcated space-occupying lesion" than "that of an infiltrating one." Still, with a tumor diagnosis following the ventricular studies, an osteoplastic flap cortex exposure was performed. There being no lesion visible on the surface, the exploring ventricular needle was utilized. The resistance met by it was the rather characteristic rubbery resistance of an

# ABSCESS OF BRAIN



FIG. 9.—The rarefaction of the frontal bones is the radiologic characteristic of osteomyelitis. Note the loss of the detail of the frontal sinus outline on the right side.

FIG. 10.—The localization in this case was dependent on the defective right anterior ventricle deformity. These studies were performed after radical excision of the osteomyelitis



abscess, so that an electrocoagulation puncture was made into the abscess cavity. The technical procedures instituted here were those already referred to, and were enforced in every detail. Although the personal experiences of the author, as well as those of many neurosurgeons, before the introduction of sulfa and penicillin therapy, in situations of this type would have prompted a malign prognosis, the experiences in Cases 1, 2, and 3 permitted a more optimistic outlook. The convalescence was that of a normal craniotomy from which a benign tumor had been totally removed.



FIG 11.—Although the volume of pus was evacuated during the dissection, when the operative split was opened for photographic detail there still remained a few cubic centimeters.

**Case 5.**—A 17-year-old boy, in June, 1945, developed a small swelling in the right frontal area, just above the eyebrow. He was told this was a "cyst." This was incised and pus obtained. This continued to drain, and a similar "cyst" developed over the left frontal area. This too was incised with purulent drainage. In the latter part of July a diplopia developed which was his chief complaint at the time of hospital admission.

*Physical Examination.* — August 10, 1945: There were encrusted draining wounds in the frontal area. There was a bilateral choked disk of four diopters. There was a left sixth nerve paralysis. There were no other neurologic objective symptoms. Roentgenograms of the skull depicted an osteomyelitis of the frontal bone (Fig. 9).

*Radical Excision Osteomyelitis — Bifrontal.*—August 14, 1945: A horseshoe-shaped flap was reflected down over both orbital ridges. The right and left frontal

bones were diseased. All grossly infected bone was removed. This left a defect some 7 cm. in diameter. Bilaterally, there were epidural granulations. There were no free cerebral pulsations demonstrable on the right or left side of the exposed sagittal sinus. Penicillin-soaked gelatin sponge strips were laid over the exposed dura. The old scalp incisional sinuses were excised and the scalp was closed in layers without drainage. The wounds healed by primary intention.

*Ventriculogram.*—August 21, 1945: Posteriorly performed ventricular air injection outlined a large right frontal horn filling defect (Fig. 10). There was a displacement of the superior portion of the anterior third ventricle to the left.

*Craniotomy.*—August 21, 1945: The previously performed scalp flap was reflected. The granulating dural surface showed no evidence of gross infection. The dura on the right side was opened for the limit of the bone exposure and to the longitudinal sinus, on the mesial side. The convolutions exposed were broadened, bulged above the dural level, and evidenced no free pulsations. An exploratory needle into the anterior pole of the right frontal lobe encountered a resistance 1.5 cm. from the surface. A 2-cm. sacrifice of the cortex was circumcised and the abscess dome bulged into the exposure. The abscess was aspirated of 15 cc. of its pus, and cupping the aspiration opening the capsule was retracted. With cotton pledget dissection and aided by the intracranial pressure, a 3.5-centimeter mass (Fig. 11) was delivered as one would such an intracerebral tumor. The hemorrhage from the bed of the dissection was very mild and easily controlled with

## ABSCESS OF BRAIN

bovine thrombin applied with the gelatin sponge packs. These strips were also soaked in penicillin. A total of 100,000 units of penicillin was left within the medullary cavity. The dura was closed tightly. Two grams of sulfanilamide crystals were powdered over the dura, and the scalp was closed in two layers with interrupted black silk sutures.

*Bacteriology.*—Smear from osteomyelitic skull: Gram-positive cocci. Culture: *Hemolytic Staphylococcus aureus*. Culture brain abscess: *Hemolytic Staphylococcus aureus*.

*Postoperative Course and Treatment.*—Sulfadiazine, 1 gram every four hours, was given by mouth for eight days. Intrathecal penicillin was given in 25,000 unit dosages



FIG. 12.—Photographed 20 days after abscess removal, healing *per primam* occurred as did this same wound after the radical sacrifice of the osteomyelitis. The stab wounds are the débrided incisions of the former "cyst" operations.

every 48 hours, for four treatments. The highest cell count in these four specimens studied was ten lymphocytes. By September 3, primary wound healing had occurred (Fig. 12), the diplopia had disappeared and the choking of the optic disks was subsiding. He was discharged from the hospital, September 17, 38 days after admission.

*COMMENT.*—This case doubly illustrates the value of chemo-penicillin as a vital adjunct to neurosurgery. The osteomyelitis was surgically eradicated, the infected dural granulations were covered with gelatin sponge strips saturated first with bovine thrombin, then with penicillin. These strips served not only as carriers for the coagulant material and the antibacterioidal agent, but served

to obliterate the dead space made necessary by sacrificing the diseased skull. When this wound was reopened seven days later there was no serum collection or gross pus, and healthy granulations were covering the dural exposure throughout. Twenty-seven days after the total removal of the brain abscess the patient was dismissed from the hospital.

TABLE I

Case	Operation	Location	Bacteriology	Treatment		Hospitalization	
				Local	Systemic	Total Days	Days after Craniotomy
I.	Decompression craniotomy	Left temporal	<i>Bacillus influenzae</i>	Sulfanilamide	Sulfapyridine	184	35
II.	Ventriculography radical mastoid. Craniotomy	Left cerebellum	Type III pneumococcus	Sulfanilamide	Sulfapyridine	48	18
III.	Ventriculography. Craniotomy	Right cerebellum	<i>Streptococcus viridans</i>	Sulfanilamide	Sulfadiazine	22	22
IV.	Ventriculography. Craniotomy	Right temporal	<i>Staphylococcus aureus</i>	Sulfanilamide Penicillin	Sulfadiazine Penicillin	21	17
V.	Radical osteo. Ventriculography Craniotomy	Right frontal	<i>Hemolytic staphylococcus aureus</i>	Sulfanilamide Penicillin	Sulfadiazine Penicillin	38	27

The results from the reports in the literature on brain abscesses that have been removed *in toto* have been surgically ideal. These wounds have healed by primary intention, and these patients have escaped the prolonged hospital complications and often fatal results that have followed all other methods of treatment. The follow-up details in these *intact* extirpations are too inadequate to evaluate with any degree of accuracy the latent sequelae, namely, convulsions that have developed following aspiration, drainage, or uncapping methods. In the five cases here reported where radical total dissections have been carried out, aided by sulfa and penicillin therapy, the hospitalization (Table I) period has been comparable to that of a normal convalescence period of any craniotomy and the morbidity, with one exception, has been *nil*. As to latent sequelae, a continued observation will be maintained. The results thus far have been such as to suggest that the basic surgical principle of "incision and drainage" in the treatment of certain abscesses of the brain might be replaced by total abscess dissection and primary wound closure.

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DISCUSSION.—DR. EDGAR F. FINCHER, Atlanta, Ga.: When Doctor Pilcher wrote me of his heroic efforts I could only say I thought he was extremely courageous.

There are many details in his manuscript that must be read to properly appreciate this contribution. In the attempt to discuss it, I find myself stymied by first, an extremely limited experience; and, second, some rather hair-raising mental gymnastics, as I recall, at the operating table when these few experiences were encountered. I think the younger neurosurgeon would do well to read and strictly adhere to Doctor Dandy's publication in 1928\* the evening before he plans a craniotomy attack on these lesions.

I can only reemphasize the main indications for operation on these patients: (1) That the lesion be remote in its location to the motor cortices or the left temporal lobe of a right-handed person; (2) that repeated dangerous spontaneous hemorrhages must have occurred; and (3) that uncontrollable convulsions constitute a primary handicap.

I am sure we are cognizant of the fortitude displayed by Doctor Pilcher in his surgical attack in these three cases and will, by virtue of his efforts, be encouraged to offer some hope for those individuals whose lesions meet the afore-mentioned criteria.

DR. WALTER E. DANDY, Baltimore, Md.: If one were looking for the ultimate test of a surgeon's skill, it would be in cases such as this. These are the most vicious lesions in the brain, without any question. His first case is a type that anyone should extirpate; it is in the right occipital lobe where only a hemianopia will result. And the subsequent absence of convulsions has justified his judgment. The extirpation in his second case was practically forced upon him, and a surgeon of less skill would certainly have lost the patient.

I have had only one complete extirpation of such a lesion. One must remember that these lesions are fed by one, sometimes two arterial branches, and from these the blood passes directly into veins or coils of vessels without an interposed capillary bed. The trick of removing these lesions is to go through the brain beyond the lesion and ligate the artery that feeds it. When that is done there will be almost no bleeding.

Certainly Doctor Pilcher deserves a great deal of credit for his fortitude and skill.

In his second case he was fortunate that it was fed by the anterior artery, not by the middle cerebral artery. There are three arteries from which the arterial blood enters the aneurysm, the anterior, middle and posterior cerebral. Those fed by the posterior cerebral are much the easiest to extirpate.

About Doctor Sachs' paper: I think he might have approached this problem in a different light and thereby have been more instructive. Abscesses vary so much in the organisms that cause them, and the results are dependent on the causative organism. So many are multiple, and that complicates the situation. Some are metastatic, others arise by direct extension. The most common organisms are *Staphylococcus aureus* and *Streptococcus*; these are more than half the total number. Single abscesses due to these organisms are easily cured by a single tap and without aspiration or drainage. Following that the abscess resolves and gradually shrinks; in other words, nature takes care of it. With other abscesses the problem differs with the organisms involved; but tapping will not cure them. If the abscesses are multiple the problem is again different and requires more than tapping.

Doctor Fincher has some nice results with extirpation. I have done several when I have encountered them unexpectedly, and with success in most of them. I can recall,

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\* Arch. Surg. Vol. 17, p. 190.

however, one patient who had complication after complication and finally succumbed. Extirpations are still dangerous despite penicillin. My feeling about abscesses is to do the least possible.

DR. ERNEST SACHS, St. Louis, Mo.: Quite a number of years ago I presented, before the American Neurological Association, a series of these lesions and called them intracranial telangiectases. I felt that they were not tumors—new growths. A number of these cases we have treated by methods different from Doctor Pilcher's. What we have done was to use a very low coagulating current and coagulated the entire lesion without extirpation. But it may be that the courageous procedure Doctor Pilcher used is more effective. Certainly, in our six or seven cases the coagulation method was effective.

Regarding Doctor Dandy's criticism, I have only this to say: In reviewing this rather large series of brain abscesses I was forced to the conclusion that extirpation was satisfactory except in cerebellar cases, and I feel sure that the ideal thing, if you have any capsule at all, is to extirpate the entire lesion.

DR. J. E. J. KING, New York, N. Y.: I want to congratulate Doctor Pilcher on his work in this group of cases and on his good results. I have seen and operated upon two cases with this condition, both being for the most part in the parietal region, and both in appearance "dead ringers" for one case especially, reported by Bronson Ray several years ago. Considering the location, it was inadvisable to extirpate either; one was partly coagulated followed by roentgenotherapy, and in the other roentgenotherapy alone was used. The latter case was that of a Negro with considerable weakness in his right hand. The last information I had from him was that he was earning his living working in a war plant.

I wish to thank Doctor Sachs for his splendid report. He has had an enormous experience. I agree with everything he stated and the manner in which he said it. One of the outstanding thoughts he left with us is that he attempts to save life regardless of what the patient's condition may be; in other words, he tries to save life regardless of what statistics may show.

With reference to Doctor Fincher's paper, I should like to say that I agree heartily with him that the original focus of the disease should be completely eradicated prior to operation for the brain abscess. I have had two cases in which the patients died from reformation of an abscess after the original abscess was well under control. The two abscesses in each case resulted from an old original extracranial focus which had not been properly operated upon.

Regarding brain abscess, in general, the ideal situation is not to have one at all. Great progress in this direction has resulted from the use of the sulfonamides and penicillin, and the incidence of brain abscess has been greatly reduced thereby. At the present time we do not see so many of these cases as heretofore.

In the past several procedures were carried out by various men, and each justified its use, for a number of cures have been effected by each method. The intention of any procedure, of course, is to get rid of the pus and abscess, prevent spreading into the meninges or ventricles, effect a cure, and prevent recurrence. Penicillin and the sulfonamides have just about "licked" meningitis. The results in the war have been magnificent so far as early injuries of the brain are concerned, and to a large degree are attributed to the proper use of these two drugs. All the information given me by former associates and personal friends confirms the opinion about the effects of these drugs in head injuries. It is well known that during World War I Doctor Cushing, with his most meticulous type of surgery, was not able to reduce the mortality rate lower than about 27 per cent, and prior to his type of surgery the mortality rate was in the neighborhood of 60 per cent, or greater.

Doctor Fincher, no doubt anticipating the intentions of a number of us, has advanced the problem supported by his knowledge of what these drugs will accomplish. In my opinion he has presented the very best procedure for operating upon brain abscesses where it can possibly be done. What could be more logical and sensible than to localize the abscess and remove it *in toto*, if possible, or piecemeal if necessary, just as one would a meningioma? It goes without saying that one cannot deal with all abscesses in this manner, but this solution is, without doubt, the one most of us have been hoping for. Doctor Fincher has proved its efficacy.

I heartily agree with him in the establishment and maintenance of the sulfa blood level and the local and intrathecal use of penicillin. In my recent experience they have proved to be good. I can recall five or six patients operated upon before the era of sulfonamides and penicillin who, I feel sure, could have been saved with the use of these drugs. More words in praise of Doctor Fincher's paper could be said, but time does not permit. He is to be highly commended for his splendid work and excellent presentation.

DR. CLAUDE C. COLEMAN, Richmond, Va.: After I have expressed my admiration for Doctor Pilcher's skill and heroic operations upon aneurysms of the brain, I should like to discuss briefly the papers of Doctors Sachs and Fincher. I have always felt that the eradication of a brain abscess should be accomplished with the least possible disturbance to the surrounding brain. Some years ago I reported 26 consecutive cases of abscess with four deaths. All these patients were treated by catheter drainage. However, I think we are prone to change our attitude toward the treatment of brain abscess and I think we should be prepared to do so. Abscesses occur in different locations with different organisms. I have had prompt recovery with simple tapping of an abscess as advocated by Doctor Dandy. In most of the cases when the patient did not show improvement after tapping or if there were progression of symptoms, I have usually attempted to insert a small drain. It seems to me the more radical treatment advocated by Doctors Sachs and Fincher should be reserved for those cases that resist simple methods of treatment. I have removed such abscesses *in toto*, with their capsule, after failing to cure them by tapping and drainage. I think there is a good deal to be said for the radical extirpation, with the capsule, in multiple abscesses or in those in which a large granulomatous mass forms which cannot be eradicated. It seems best that one should be prepared to use more than one procedure, dependent on the abscess.

Doctor King, who has had a large experience in the treatment of abscess, states he does not see as many of them as formerly. This is true in my experience. With better eradication of mastoid and frontal sinus infection, and with the use of the sulfonamides and penicillin, brain abscesses should become more rare. With these drugs and the proper handling of suction, I believe one can use the procedure advocated by Doctors Sachs and Fincher with very much more chance of success than was formerly possible.

## STREPTOMYCIN IN URINARY INFECTIONS\*

MAJOR BORIS P. PETROFF, M.C., A.U.S.,

AND

2ND LIEUT. FRED V. LUCAS, SN.C., A.U.S.

THE UROLOGIC PROBLEM IN PARAPLEGIA is that of urinary infection, which takes place when catheter or suprapubic drainage are instituted. Mixed infection results which first involves the lower urinary tract in the form of cystitis and urethritis often accompanied by epididymitis and periurethral abscess, and then migrates to upper urinary tract with resultant pyelonephritis, cortical abscesses and in some cases formation of calculi.

A total of 87 patients (with neurogenic bladders due to involvement of central nervous system) have been admitted to Newton D. Baker General Hospital since October, 1944, of whom 77 were paraplegias due to spinal cord injuries. Forty of these had suprapubic cystostomies and heavily infected urine.

TABLE I

### BACTERIA FOUND IN PARAPLEGIC BLADDERS

A Aerogenes	..	39%
Colon Intermediate	.	18%
B Proteus	. . .	15%
Paracolon	.	12%
B Pyocyaneus		8%
Staph Aureus	.	5%
Alpha Strep	. . . .	3%

The balance were emptying their bladders spontaneously but were also infected. The suprapubic cystostomies were changed over to urethral catheters, allowed to close and placed on tidal drainage, using Suby and Albright's M solution (citric acid buffered solution) having a  $p_H$  of 4.5.

Urine cultures showed a mixture of organisms, gram-negative bacilli and gram-positive cocci. The gram-negative bacilli were predominant (Table I).

Between October, 1944 and April, 1945, despite all aseptic precautions in the use of tidal drainage, each patient had an average of one to three elevations of temperature a month, often attended by chills. There were eight cases of renal calculi of which one was bilateral, nine epididymites, eight periurethral abscesses, three positive blood cultures of *Aerobacter aerogenes* and *Bacillus proteus*, and there was one death due to cortical abscesses infected with *A. aerogenes*.

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\* Read before the Fifty-seventh Annual Session of the Southern Surgical Association, December 4-6, 1945, Hot Springs, Virginia.

# STREPTOMYCIN IN URINARY INFECTIONS

Streptomycin Treatment for Infection with Gram-Negative Bacteria  
in Voiding Neurogenic Bladders with Upper Urinary Tract Changes

CASE	AMOUNT AND DOSAGE OF STREPTOMYCIN	LOT NO.	REACTIONS	BACTERIA IN URINE BEFORE TREATMENT	BACTERIA 4-7 DAYS AFTER TREATMENT	LEVELS IN UNITS OF STREPTOMYCIN			
						6 HRS AFTER START	12 HRS AFTER START	24 HRS AFTER START	48 HRS AFTER START
1 Ho Residual 180 cc Nephrectomy-Stone	200,000 Units 1 M + 100,000 Q 3 Hrs Total 500,000 in 12 Hrs	212	None	A Aerogenes	A Aerogenes	317	35	296	5.0
2 Kir Kidney and Ureteral stone	"	212	None	A Aerogenes Staph Aureus	Sterile	348	-	270	-
3 Ho Residual Urine 50 cc	200,000 Units 1 M Repeated Q 3 Hrs Total 1,000,000 in 15 Hrs	187	Headache	A Aerogenes	Sterile	280	113	218	4.0
4 Sn Blind Ureter Relaxed Sphincter	"	187	Headache Joint pains Temp 101.0 F	A Aerogenes B Proteus	Sterile	305	4.0	52.0	13.0
5 Kir Ureteral stones	"	187	Headache	A Aerogenes B Proteus	Sterile	255	-	22.0	-
6 Pl. Relaxed Sphincter	"	187	None	A Aerogenes	Sterile	22.0	4.0	31.0	7.0
7 We Relaxed Sphincter	"	187	Headache Joint pains	B Proteus Para colon E Coli Staph Aureus	Sterile	22.0	1.8	25.5	8.0
8 Po Residual Urine 60 cc	"	187	None	A Aerogenes	Sterile	22.0	1.0	-	-
9 Ek Relaxed Sphincter Incontinence	"	187	Headache	A Aerogenes	Sterile	22.0	1.0	-	-
10 Br Residual Urine 200 cc	"	187	None	A Aerogenes	Sterile	22.0	1.0	-	-
11 Ja Relaxed Sphincter Incontinence	200,000 Units 1 M and 100,000 U Q 3 Hrs Total 1,000,000 in 24 Hrs	226	Headache	A Aerogenes B Proteus	Sterile	270	1.2	21.5	1.5
12 Kr Relaxed Sphincter	"	226	None	A Aerogenes B Proteus Staph Albus E Coli	2 colonies A Aerogenes Few B Proteus Staph Albus	520	8.0	470	3.8
13 Ki Residual Urine Bladder stone	"	212	None	A Aerogenes B Proteus Staph Aureus	Staph Aureus B Proteus fewer colonies	360	2.8	42.0	-
				B Proteus Fewer colonies	B Proteus fewer colonies	296	21.5	1.0	-
				B Proteus	B Proteus	370	6.0	29.5	1.0

Table II.—Table of 13 cases.



# Streptomycin Treatment for Infection with Gram-Negative Bacteria In Neurogenic Bladders on Catheter Drainage and with Upper Urinary Tract Changes

CASE	AMOUNT AND DOSE OF STREPTOMYCIN	LOT NO.	REACTION	BACTERIA IN URINE BEFORE TREATMENT	BACTERIA 24-48 HRS AFTER TREATMENT	BACTERIA 4-7 DAYS AFTER TREATMENT	LEVELS IN UNITS OF STREPTOMYCIN			
							6 HRS AFTER START		12 HRS AFTER START	
							Urine	Blood	Urine	Blood
1 Sn Ureth Cath Catheter	200,000 Units IM 4 100,000 Q 45 Hrs Total 500,000 In 12 hrs	212	Headache	A. Aerogenes E. coli Staph. Alb.	B. Pyocyaneus Staph. Alb.	B. Pyocyaneus Staph. Alb.	21.5	0.4	24.5	0.5
2 Sn Ureth Cath	-	212	None	B. Proteus B. Pyocyaneus	B. Pyocyaneus	B. Proteus B. Pyocyaneus	21.6	0.5	21.6	0.5
3 Hn Ureth Cath	-	212	None	E. coli B. Proteus Colon Intermediate (Aerogenic)	B. Proteus Colon Intermediate (Aerogenic)	B. Proteus Colon Intermediate (Aerogenic)	21.5	0.4	21.5	0.5
4 Co Ureth Cath + Tistula Rt Renal Calculi Temp 102° F	-	212	None	A. Aerogenes S. Streptococcus (Temp 102° F)	S. Streptococcus Colon Intermediate (Temp 102° F)	A. Aerogenes B. Pyocyaneus Staph. Aureus E. coli	20.0	0.4	20.5	0.5
5 Ph Ureth Cath	200,000 Units IM Regular 0.5 Hrs Total 1,000,000 In 15 Hrs	187	None	A. Aerogenes B. Proteus	A. Aerogenes few colonies	A. Aerogenes	26.0	1.0	24.0	11.5
6 Gs Ureth Cath Rt Calculi Pycnophros	-	187	None	A. Proteus A. Aerogenes	Sterile	A. Aerogenes B. Pyocyaneus	44.5	3.2	52.0	8.0
7 Gs Ureth Cath	-	187	None	A. Aerogenes	Sterile	Colon Intermediate (Aerogenic)	42.0	12.0	44.5	8.0
8 Gs Ureth Cath Epididymitis	-	187	None	A. Aerogenes E. coli Staph. Aureus	A. Aerogenes Staph. Aureus	A. Aerogenes Staph. Aureus	50.5	2.0	52.0	9.8
9 Lss Ureth Cath Ureth Fistula	-	187	None	A. Aerogenes B. Pyocyaneus E. coli Staph. Aureus	Sterile	A. Aerogenes B. Pyocyaneus	49.5	3.2	52.0	9.8
10 Don Ureth Cath + Tistula Rt Renal Calculi	-	187	None	A. Aerogenes Colon Intermediate	Sterile	A. Aerogenes	15.5	1.6	16.7	12.3
11 Gs Ureth Cath	-	187	None	A. Aerogenes E. coli Staph. Aureus	A. Aerogenes Staph. Aureus	A. Aerogenes B. Pyocyaneus E. coli	8.5	1.0	-	-
12 Hn Ureth Cath + Tistula	-	187	None	A. Aerogenes Colon Intermediate	A. Aerogenes (few colonies)	A. Aerogenes	22.0	0.8	51.0	0.9
13 Gs Ureth Cath Calculi Pycnophros Temp 102° F	200,000 Units IM 4 100,000 Q 5 Hrs Total 1,000,000 In 24 Hrs	226	Headache	B. Proteus	Sterile temp 102° F	B. Proteus	55.6	8.8	42.0	2.0
14 Hn Ureth Cath + Tistula	-	226	Headache	A. Aerogenes B. Proteus	Sterile	Sterile	29.6	-	42.0	-
15 Rm Suprapubic Cystostomy	-	226	None	A. Aerogenes B. Pyocyaneus B. Proteus Colon Intermediate	Sterile Urine full of abscess	Sterile (no infection of Urinal)	53.7	0.5	31.6	1.0
16 Bn Ureth Cath Fistula	-	226	None	A. Aerogenes B. Proteus	Sterile	A. Aerogenes	34.0	8.0	51.0	8.0
17 Dol Ureth Cath Tistula Rt Orchiectomy	-	226	None	A. Aerogenes E. coli Staph. Aureus	A. Aerogenes B. Proteus	B. Pyocyaneus E. coli A. Aerogenes	27.0	1.0	29.0	2.0
18 Co Suprapubic Cystostomy	-	226	None	E. coli Colon Intermediate (Aerogenic)	Sterile	E. coli Colon Intermediate few colonies	24.5	2.0	14.2	1.0
19 Ke Ureth Cath	-	226	None	A. Aerogenes	A. Aerogenes few colonies	A. Aerogenes	29.5	2.7	24.5	1.5
20 Bn Ureth Cath - Fistula	-	226	None	A. Aerogenes B. Proteus B. Pyocyaneus	A. Aerogenes E. coli	A. Aerogenes E. coli	29.5	12.0	21.5	2.0
21 La Suprapubic Cystostomy	-	226	None	A. Aerogenes	Sterile	Aerogenes	43.0	14.2	45.0	8.9
22 Co Ureth Cath	Local Streptomycin as Tidal Drainage 600 Q cc in H Saline Sol	None	None	A. Aerogenes B. Streptococcus	A. Aerogenes E. coli	A. Aerogenes Colon Intermediate				
23 Ph Ureth Cath	-	None	None	A. Aerogenes	A. Aerogenes few colonies	A. Aerogenes				
24 Suu Ureth Cath	Local Streptomycin as Tidal Drainage 600 Q cc in H Saline Sol	None	None	A. Aerogenes	A. Aerogenes few colonies	A. Aerogenes				
25 Hn Ureth Cath	-	None	None	A. Aerogenes	A. Aerogenes few colonies	A. Aerogenes				

Table III.—Table of 25 cases.

At first, the only available means of controlling urinary infections were penicillin and sulfonamides. We were reluctant to use sulfonamides since paraplegic patients developed anorexia from their use. Penicillin was used extensively and cleared the urines of staphylococci and streptococci, leaving the gram-negative bacilli unaffected.

Streptomycin in Paraplegia with Catheter

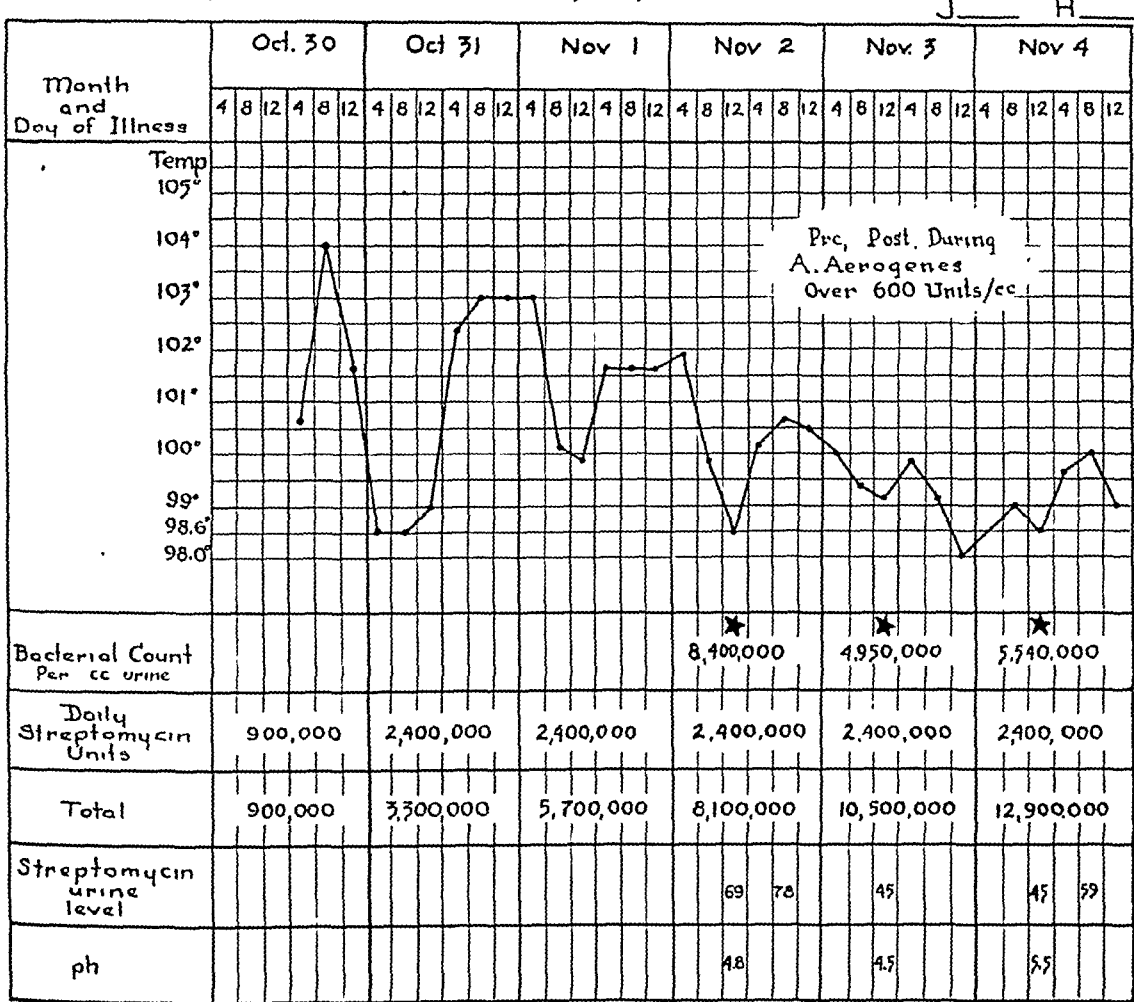


CHART I.—Cervical cord injury (C 7, partial), urethral catheter and pyelonephritis.  
(cont'd on Chart II)

A new antibiotic, Streptomycin, was obtained in April, 1945. From the work of Schatz, Bugie and Waksman, and Robinson, Smith and Graessle it was known to inhibit gram-negative bacilli.\*

Preliminary, *in vitro* studies in the laboratory demonstrated that *A. aerogenes*, *B. proteus* and *B. pyocyaneus* were inhibited by 25 units of Streptomycin per cc. in an F.D.A. broth culture.

\* Streptomycin first was furnished by Merck & Company, Rahway, New Jersey. Appreciation is extended to their staff for many helpful suggestions and materials contributed.

When Streptomycin was given to patients intramuscularly in doses of 200,000 units every three hours, it was found by biologic assay that urine levels of 15 to 50 units could be attained at the end of three hours (Table II).

A series of 13 patients with no catheters but having infected neurogenic bladders were given a course of 1,000,000 units of Streptomycin each. After start of treatment at the end of six to nine hours urine cultures were found to be sterile; however, all but one developed reinfection with gram-negative bacilli within four to seven days after the treatment had been discontinued.

### Streptomycin in Paraplegia with Catheter

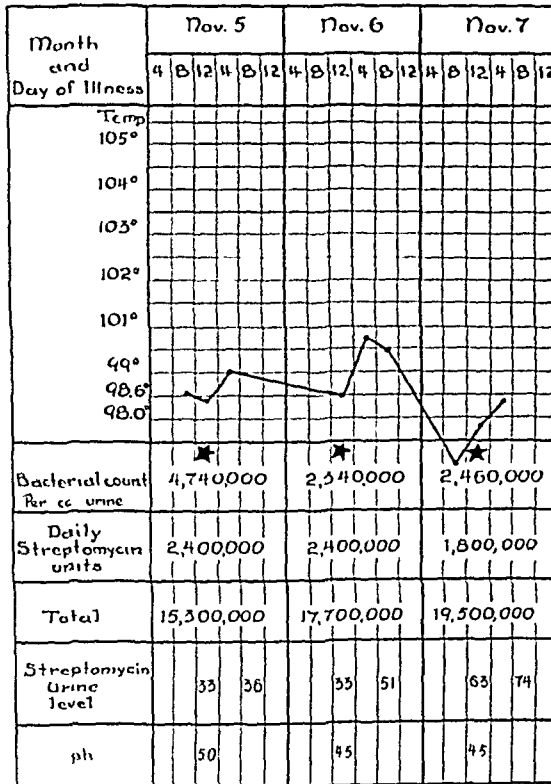


CHART II.—(continuation of Chart I).

When Streptomycin was first used in an attempt to control urinary infection in 26 paraplegic patients with indwelling catheters, the urines in ten of them became sterile at the end of 24 hours. However, in four to ten days after the treatment was stopped all became reinfected. Obviously, the catheter was the portal of infection. Local irrigation was tried in four cases using Streptomycin solution containing 160 to 600 units per cc. The cultures remained positive (Table III).

As more Streptomycin became available it could be used for prolonged periods and in larger doses. Paraplegic patients were given 300,000 units intramuscularly every three hours, until levels up to 70 to 100 units per cc. in

the urine could be obtained. At this time, it became apparent that gram-negative bacilli already exposed to Streptomycin developed strains resistant to it, or became Streptomycin-fast. Patients with *A. aerogenes* and *B. proteus* infections which could be cleared up by 25 units or less per cc. in April, by June, developed strains of these bacteria which were resistant to 600 to 700, and some

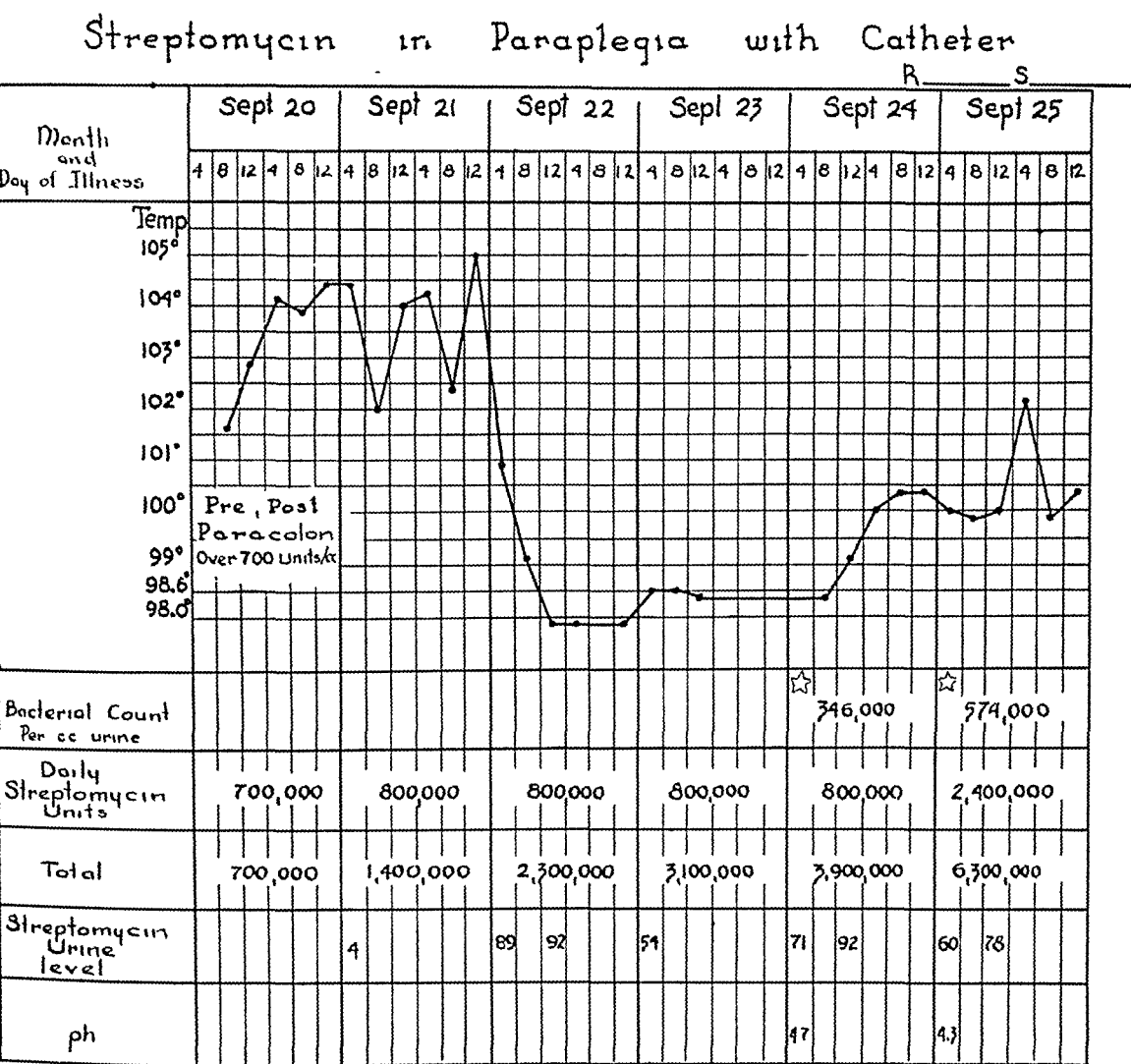


CHART III.—Complete cord transection at D 8, urethral catheter and pyelonephritis (cont'd on Chart IV)

to over 1,000 units per cc. As it is not feasible to obtain such high concentration of Streptomycin in the urine it would be impossible to destroy these bacteria completely. However, clinically, the patient improved when Streptomycin was given, temperatures were lowered more rapidly than before and colony counts in urine cultures definitely diminished. Fluid intake of these patients was kept at 3,000 cc. per 24 hours. Thus, Streptomycin was used routinely on all paraplegics who showed signs of increasing urinary infection, such as elevated temperatures, chills, increasingly cloudy urine and toxemia. It definitely reduced unpleasant complications.

# Streptomycin in Paraplegia with Catheter

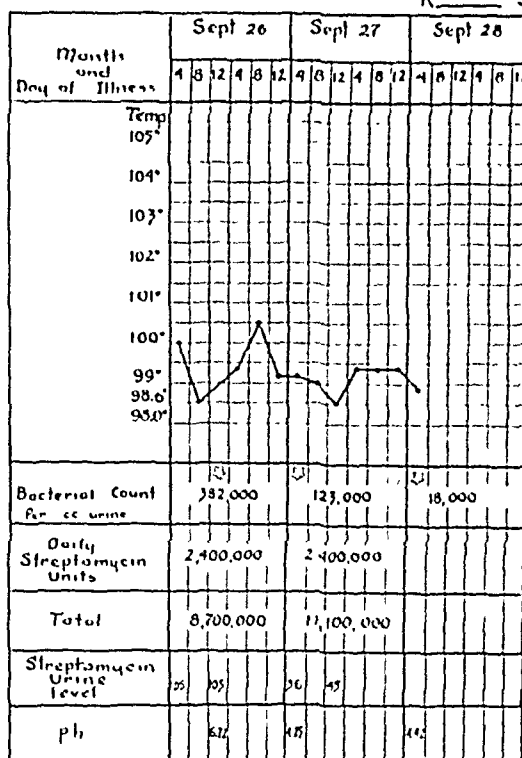


CHART IV.—(continuation of Chart III)

# Streptomycin in Paraplegia with Catheter

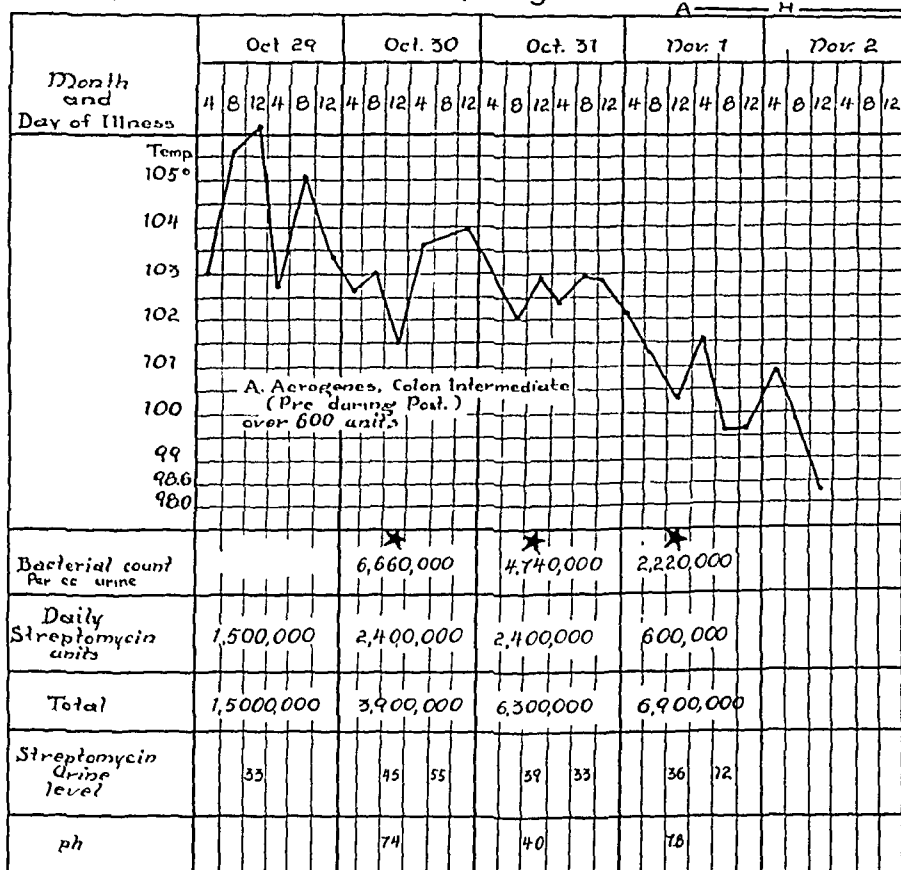


CHART V.—Cervical cord injury (C 7, partial) with urethral catheter and pyelonephritis.

STREPTOMYCIN IN URINARY INFECTIONS

Streptomycin in Paraplegia with Catheter

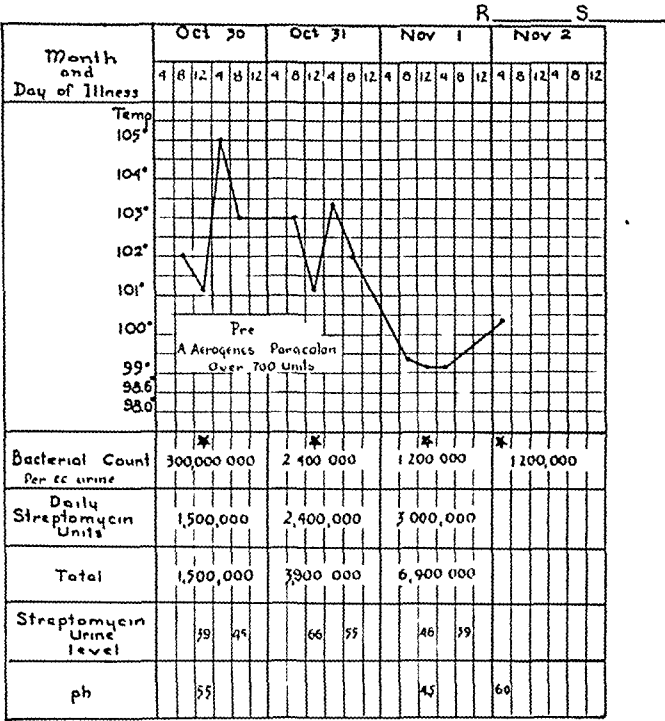


CHART VI.—Complete cord transection at D11, with urethral catheter and pyelonephritis (cont'd on Chart VII).

Streptomycin in Paraplegia with Catheter R-S—

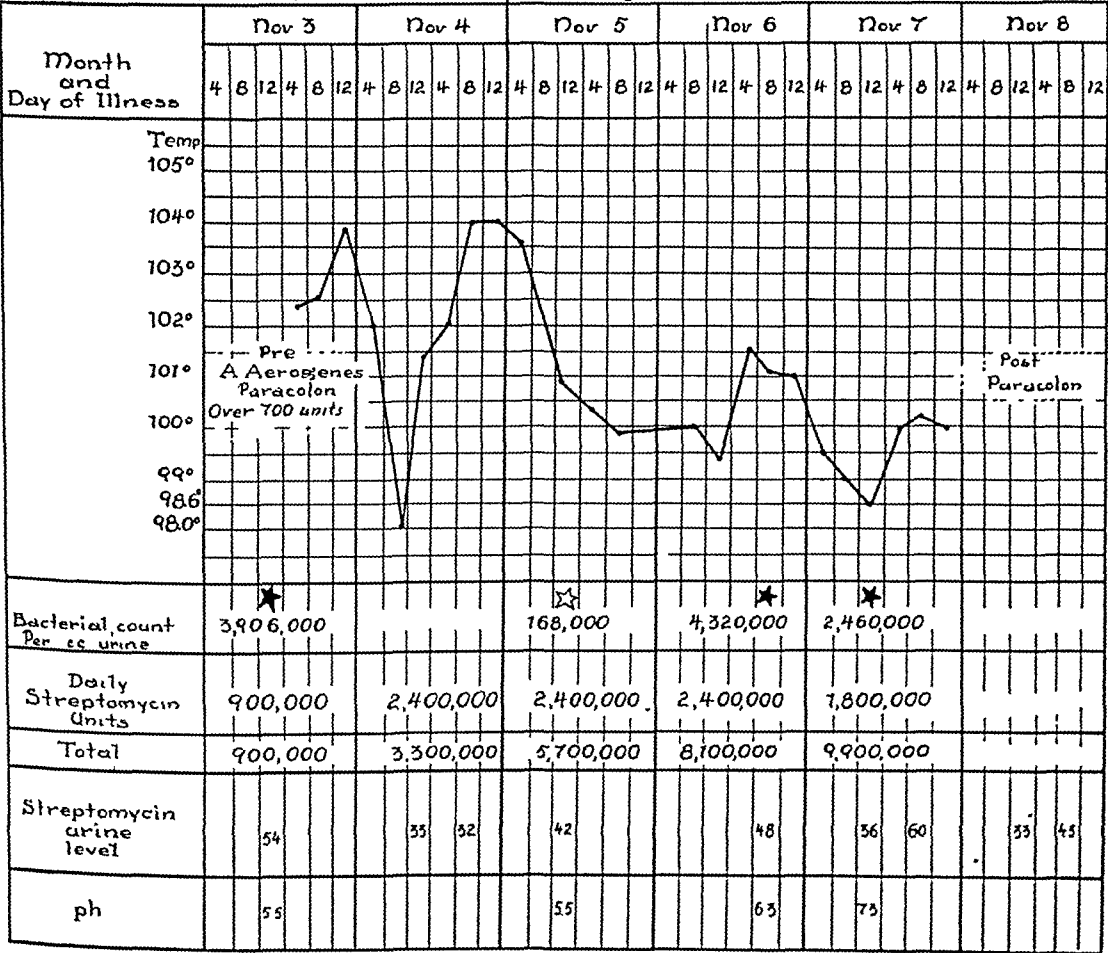


CHART VII.—(continuation of Chart VI)

It was noted in the laboratory that the colony morphology of the gram-negative bacilli changed after patient had been treated with Streptomycin. *A. aerogenes* colonies became flat, rough and dry instead of being mucoid. *B. proteus* began to grow in isolated colonies instead of spreading and overgrowing the plate. This would confirm the observations of Robinson, Smith and Graessle, based on experiments carried on *in vitro*, to the effect that the

### Streptomycin in Paraplegia with Catheter

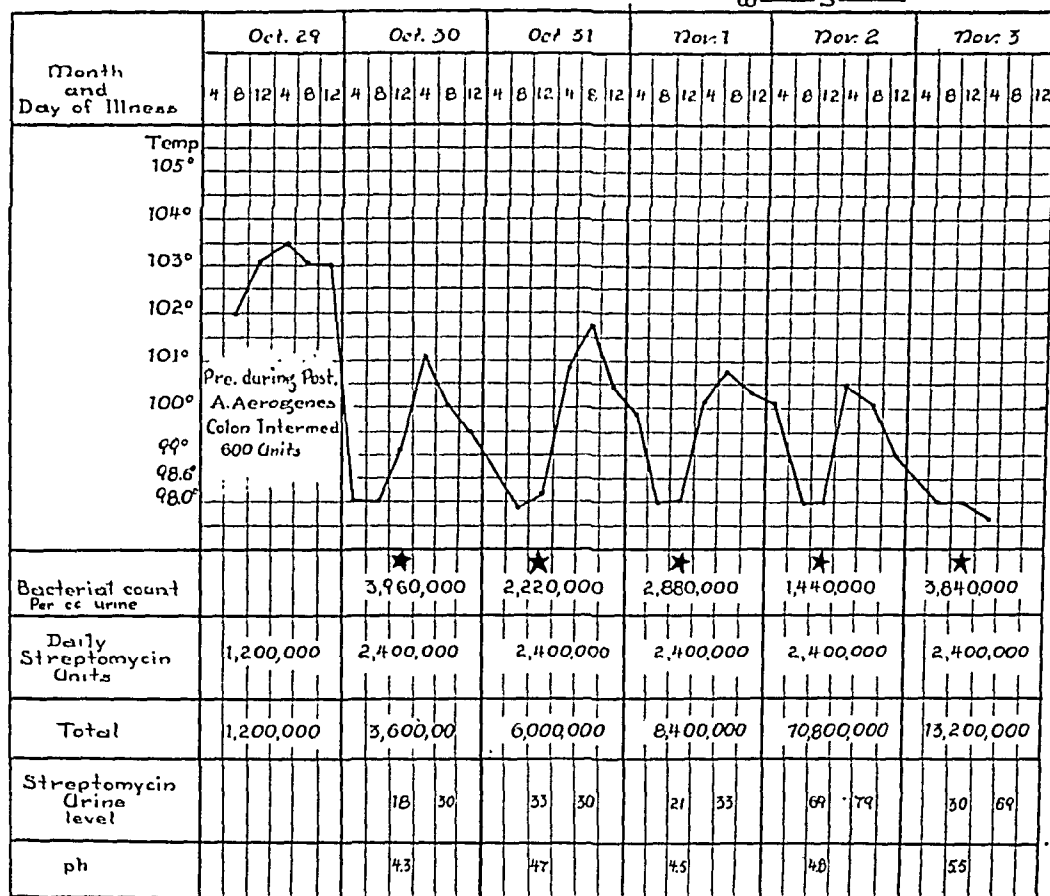


CHART VIII.—Complete cord transection at D10, with urethral catheter and pyelonephritis.

pathogenicity may be reduced and morphologic changes occur with resulting decrease in multiplication of bacteria even if the bacteria are not completely destroyed.

Charts of patients' reaction to Streptomycin are shown, indicating the colony count per cc. of urine decreased as temperature drops. Toxic reactions from Streptomycin were slight; 20 per cent of patients receiving it complained of frontal headaches, joint pains and malaise. Two per cent had a temperature rise up to 101° F. These toxic effects were ascribed to histamine-like constituents in certain batches of Streptomycin and have decreased as methods of manufacture have improved. Liver and kidney function tests on all patients

before and after treatment showed that no impairment followed use of Streptomycin (Chart II-VIII).

Urinary calculi and abscesses of kidney and lower urinary tract cannot be expected to respond to Streptomycin given parenterally, unless treated surgically first. Local irrigation of renal pelvis in the presence of obstructing calculi and local irrigations of testicular abscesses with Streptomycin solution 5,000 units per cc. (high concentration necessary because of increasing bacterial resistance to Streptomycin), were of limited value in affecting the bacteria, although, clinically, these treatments seemed to reduce the virulence of infection. No objective evidence can be proffered at present that resistant gram-negative bacilli are rendered less pathogenic by Streptomycin, but with more laboratory work it may be found that diminution in their motility, loss of their capsule, as well as reduction in their urea-splitting, stone-forming faculties do occur. Streptomycin is probably the only specific antibiotic at present which will control these intractable gram-negative bacillary infections of the urinary tract, so common in patients with incompetent internal sphincters and indwelling catheters. Since almost identical bacterial flora is found in stool cultures of paraplegic patients, as in their urine the question of cross-infection between individuals on a ward must be considered, as well as possibility of direct invasion of colon bacteria into the paralyzed urinary tract. Constant vigilance on the part of the urologist is necessary to prevent overwhelming infiltration of gram-negative bacilli into this susceptible medium.

Streptomycin has been proven to be a valuable antibiotic aid in controlling heretofore intractable urinary infections. However, the principles of sound urologic and surgical practice still apply. These are: good drainage without residual urine; elimination of mechanical obstruction; and clearing of foci of infection and removal of avenues of infection, such as the catheter. So long as paraplegic patients possess incompetent sphincters they will have urinary complications. These infections are controlled by antibiotics, such as Streptomycin, but they are not eradicated.

#### SUMMARY

1. Streptomycin was used in 13 cases of neurogenic bladders voiding without catheters—nine became sterile but were reinfected in four days.
2. Streptomycin was used in 22 cases of neurogenic bladders with catheters indwelling, ten became sterile in 24 to 48 hours, two remaining sterile for four days, but all had a recurrence of infection.
3. Local irrigation with Streptomycin solution has a limited value.
4. Gram-negative bacilli became resistant to Streptomycin once exposed to it and not completely destroyed.
5. Clinical improvement and lowered colony counts were noted in urine cultures of paralyzed patients infected with Streptomycin-resistant bacteria, when larger doses of Streptomycin were given.
6. Morphologic changes have been noted in gram-negative bacilli exposed to Streptomycin.



## CONCLUSIONS

Streptomycin is an important new antibiotic useful in controlling gram-negative bacilli infecting the urinary tracts of paraplegic patients. Therapy should be based on sensitivity of the organisms to the antibiotic, and dosage and length of administration adjusted according to severity of infection, large initial doses being the most efficacious.

Appreciation is extended to Miss C. Gunn, Miss M. Meyer and Miss M. Reilly for the help they have given in the laboratory.

Acknowledgment is made to Col. E. L. Cook, Commanding Officer of Newton D. Baker General Hospital for his interest and to Col. D. H. Poer, Chief of Surgical Service, for his kind suggestions and aid in preparing this report.

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## A NEW METHOD FOR CONSTRUCTING AN ARTIFICIAL ESOPHAGUS\*

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THE PURPOSE of this communication is to report a new method for constructing an artificial antethoracic esophagus. A loop of jejunum which is ultimately completely isolated from its mesenteric blood supply is implanted in a skin tube and is transferred to the anterior chest wall in order that it may serve as a channel between the upper part of the esophagus and the stomach.

In all of the numerous previously devised methods for transferring various segments of the alimentary tract to the anterior chest wall, the mesenteric blood supply has been retained. The use of a segment of intestine as a free graft has apparently not been previously described.

In the surgical treatment of malignant esophageal lesions there is a growing tendency to reestablish the continuity of the alimentary tract at the time of the excision of the original lesion by mobilization of all or a part of the stomach or jejunum. The reports of Garlock,<sup>1</sup> Sweet,<sup>2</sup> Clark,<sup>3</sup> and others, indicate that such primary anastomoses may be successfully performed for lesions as high as the arch of the aorta. If wide excision of the growth is not hampered, and if the operative mortality is not excessive, such one-stage procedures are certainly to be preferred to the older Torek operation. There are, however, still numerous cases in which, because of the location or extent of the growth, the poor general condition of the patient, or unfavorable results from mobilization of the stomach or jejunum, it is necessary to exteriorize the oral end of the esophagus and to perform some type of delayed esophageal reconstruction. The impermeable benign strictures of the esophagus, unless they are so localized that resection and primary anastomosis may be feasible, are at present probably best treated by some type of antethoracic reconstruction. Delayed esophageal reconstruction may also be indicated in cases of congenital atresia when a primary anastomosis cannot be performed.

The technic described in this paper was first proved to be feasible in a series of experimental animals, and it has subsequently been used on three patients. In one patient the procedure has been completed. A brief review of these cases will be given after the experiments have been described.

In the past, interest in isolated intestinal segments has chiefly been confined to the study of the physiology of the alimentary tract and its reaction to various drugs. Puestow,<sup>4</sup> in 1932, exteriorized various segments of the small intestine and partially embedded them in an abdominal incision. At a later date these segments were separated from all their mesenteric attachments. After division

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\* Read before the Fifty-seventh Annual Session of the Southern Surgical Association, December 4-6, 1945, Hot Springs, Virginia.

of the entire mesentery the peristaltic response to eating was less than normal. This he attributed to division of the mesenteric nerves. In 1939, Reagan and Puestow<sup>5</sup> prepared similar isolated segments of the colon and found that their response to various drugs was unchanged by division of the mesenteric vessels and nerves.

In 1942, Davis and Stafford<sup>6</sup> reported a case from the Surgical Service of the Johns Hopkins Hospital in which, using Lexer's method, they had successfully constructed an antethoracic esophagus. The ultimate fate of the blood supply of the transplanted jejunal segment aroused their interest.

#### EXPERIMENTAL OBSERVATIONS

Shortly after the completion of this reconstruction by Davis and Stafford, Doctor Stafford began a series of experiments on dogs which were designed to determine whether small segments of the intestinal tract would survive as free grafts, isolated from the mesenteric blood supply, when transplanted into the subcutaneous tissue of the abdominal wall. During Doctor Stafford's absence with the 18th General Hospital the experiments were completed by us, and they are included in this report with his permission.

**SERIES 1.**—Four dogs were used. A single primary mesenteric artery and vein of the upper jejunum were isolated and a small segment of intestine supplied by these vessels was resected. The resected segment was placed in a subcutaneous tunnel with the mesenteric artery and vein passing through the abdominal wall. The ends of the intestine were brought to the outside through stab wounds in the skin. One of these animals died of distemper several months after operation. Nine months after operation the remaining three dogs were explored and the mesenteric vessels divided. All the intestinal grafts survived and showed no ill effects from the procedure (Fig. 1).

It then occurred to one of us (M. M. R.) that a longer segment of intestine might be isolated, enclosed in a skin tube, and transplanted into any desired position, and that it might be possible to construct a complete antethoracic esophagus from such a jejunal graft.

**SERIES 2.**—In the second series of experimental animals nine such intestinal-skin tubes were prepared in the following manner: A right rectus incision was made and the upper jejunum was identified. In this region the primary intestinal arteries anastomose through a single arcade which lies close to the mesenteric border of the jejunum. The terminal arteries arise from the arcade and pass directly to the intestine. By careful selection a segment of jejunum 15 to 20 cm. in length can be found which will be nourished by a single primary intestinal artery and vein. After selecting such a vessel and segment of jejunum, we isolated the intestine and freed the vessels from the mesentery. The continuity of the intestinal tract was restored. A skin tube of sufficient length and width was undermined adjacent to the original incision. A stab wound was made through the musculature of the abdominal wall beneath the central portion of the skin tube and the jejunal loop delivered through this wound. The peritoneum and musculature of the original incision were closed.

# ARTIFICIAL ESOPHAGUS

The intestine was enclosed in the skin tube with a central pedicle about the intact mesenteric vessels. The ends of the jejunal graft were brought out through stab wounds at either end of the skin tube.

FIG. 1

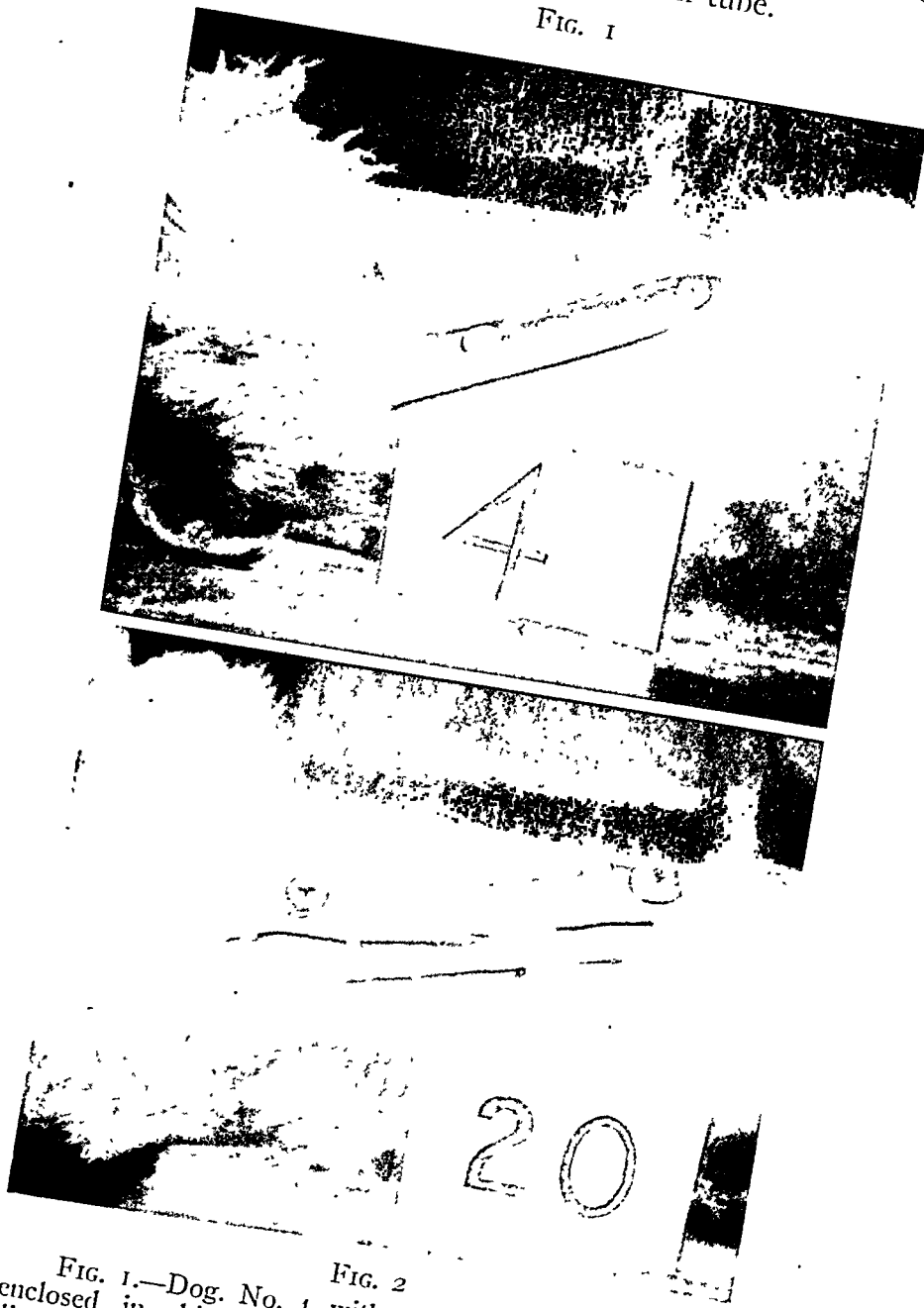


FIG. 1.—Dog. No. 4, with short segment of jejunum enclosed in skin tube. Mesenteric vessels completely divided.

FIG. 2.—Dog No. 20. Long segment of jejunum enclosed in skin tube with intact mesenteric vessels passing through central pedicle.

In five of the nine dogs the results were considered good. The entire jejunal loop survived, and the skin tube healed satisfactorily (Fig. 2). The results were fair in two dogs. The skin tube healed satisfactorily but there was loss of a part of the jejunal loop. In two dogs the jejunal transplant became completely gangrenous. The most likely explanations were that the mesenteric ves-

sels had been twisted at the time the loop was brought out through the stab wound or that the central pedicle was made too small and the vessels had been constricted.

In the six experiments in which the loop remained viable, six weeks later the central pedicle was clamped with a rubber-shod clamp for progressively longer periods of time in order to hasten the establishment of collateral circulation. When the collateral circulation seemed adequate, the central pedicle was divided and the mesenteric vessels were ligated (Fig. 3). Division of the

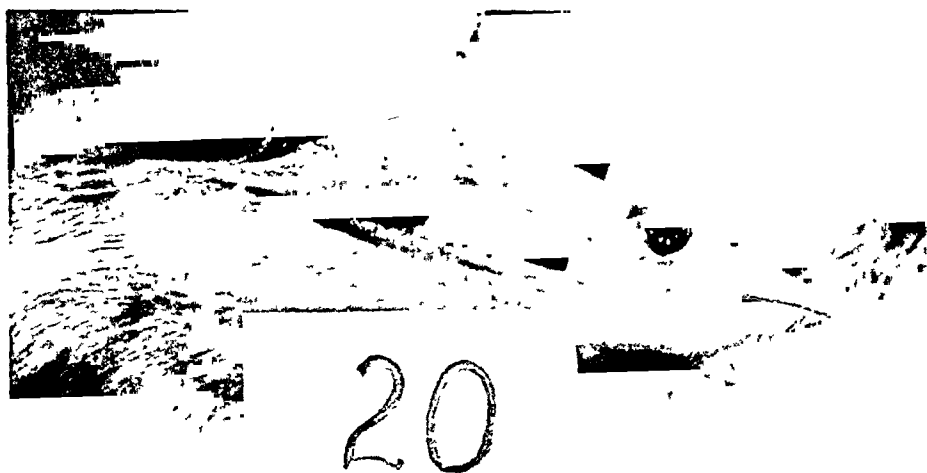


FIG. 3.—Dog No. 20, with mesenteric vessels and central pedicle divided.



FIG. 4.—Dog No. 20, with intestinal-skin tube transplanted to anterior thorax. Catheter inserted into intestinal segment.

mesenteric vessels in four of the dogs had no permanent effect on the jejunum or the skin tube. One tube in which there was partial loss of jejunum following the first stage showed further loss of the intestine after the second operation, leaving only about one half of the original jejunal loop. In the remaining experiment, in which partial loss of the jejunum occurred after the first stage, the entire segment disappeared after the mesenteric vessels had been divided.

One week later, after satisfactory tests with intermittent occlusion, the lower pedicle was divided. The caudal end of the intestinal-skin tube was rotated to the upper thoracic region, opened and implanted (Fig. 4). This procedure was carried out on four dogs. Two of the transplanted intestinal-skin tubes healed *per primam*. Infection beneath the tube in the other two dogs caused partial loss of the graft.

In one dog in which a satisfactory intestinal-skin tube had been rotated to the anterior chest wall an attempt was made to anastomose the proximal end of the esophagus and the stomach to the transplanted intestine. This animal died on the fifth postoperative day of an extensive gas infection of the cervical region following leakage from the upper anastomosis. Further attempts to complete the procedure in other animals were not made because of inadequate personnel to care for the dogs during the postoperative course when intravenous fluids and other forms of treatment were necessary.

Four months after the mesenteric vessels had been divided the isolated jejunal grafts showed evidence of moderate atrophy of the musculature but were otherwise grossly normal. The mucosa appeared normal and continued to secrete small amounts of mucoid material. Peristaltic movements were frequently seen, arising both spontaneously and from mechanical stimulation such as pinching or distending the intestine. On microscopic examination the normal architecture of the intestine was seen to be preserved.

These experiments demonstrated for the first time that a long segment of the jejunum, when placed within a skin tube, develops sufficient collateral circulation to allow division of the mesenteric vessels, and that by means of such an intestinal-skin tube, free jejunal grafts might be transferred from the abdomen to the chest and neck.

#### CLINICAL AND OPERATIVE PROCEDURE

From the experience gained in the experimental work on animals, we were encouraged to attempt the method on patients. The technic used clinically by one of us (W. P. L., Jr.) has varied from the experimental procedure only in detail; the principles are the same. The major difference has been that the entire procedure has been divided into more stages.

There are five principal steps in the procedure. Certain of these, however, may necessitate multiple stages and variations depending upon the conditions that are met. Familiarity with the technic of the formation and transfer of skin tubes is essential before undertaking the procedure.

STEP 1.—The level of the esophageal stricture is carefully determined by roentgenologic and esophagoscopy examination, and the distance from the cervical region above the stricture to a point below the costal margin is measured. The isolated intestinal loop is made somewhat longer to allow for shrinkage during transfer. The future position of the isolated loop when transplanted into the subcutaneous tissue of the left thoraco-abdominal region is determined, and the outline of the proposed skin tube that will eventually enclose the intestine is marked with brilliant green. This outline is made before the first stage

is carried out so that the original left upper rectus incision may be made through the skin and subcutaneous tissue in line with the medial edge of the proposed skin tube (Fig. 5 A).

The abdomen is opened through this incision and the first portion of jejunum is identified. The vascular pattern of the mesentery is inspected and a segment of jejunum of the desired length is selected. To obtain a sufficient length of jejunum in the human being it is necessary to select one primary

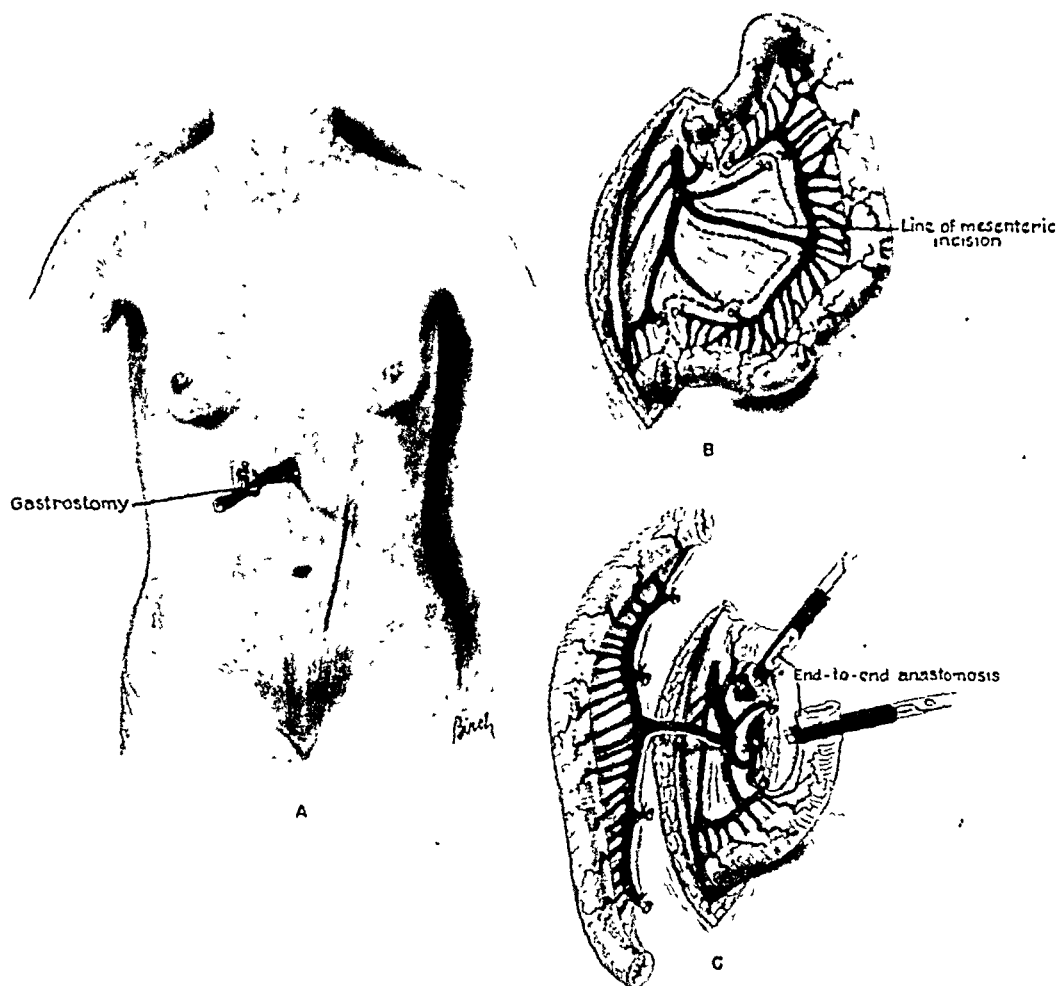


FIG. 5.—(A) Location of original left rectus incision.

(B) Line of division of intestine and mesentery.

(C) Jejunal segment isolated with single mesenteric artery intact. Mesenteric veins not shown.

mesenteric artery and vein which are to remain intact and to divide a similar set of vessels on either side of this point (Fig. 5 B). The arcuate vessels do not lie as near the mesenteric border of the jejunum in the human being as they do in the dog, and thus the isolated segment with its vascular supply is bulkier in the human being. The segment is cut from the jejunum and the continuity of the intestinal tract is restored by anastomosing the two ends. The isolated loop is now attached by a single primary mesenteric artery and vein (Fig. 5 C).

The skin and subcutaneous tissue of the lateral border of the incision are elevated from the musculature and a subcutaneous tunnel dissected above and below the area beneath the proposed skin tube. A stab wound is made through the musculature and peritoneum beneath the mid portion of the skin tube, and the isolated jejunum is delivered through this incision. The jejunal segment is now implanted in the subcutaneous tunnel and the ends are brought to the outside by means of stab wounds through the skin at the limits of the tunnel.\* The mesenteric artery and vein are left intact

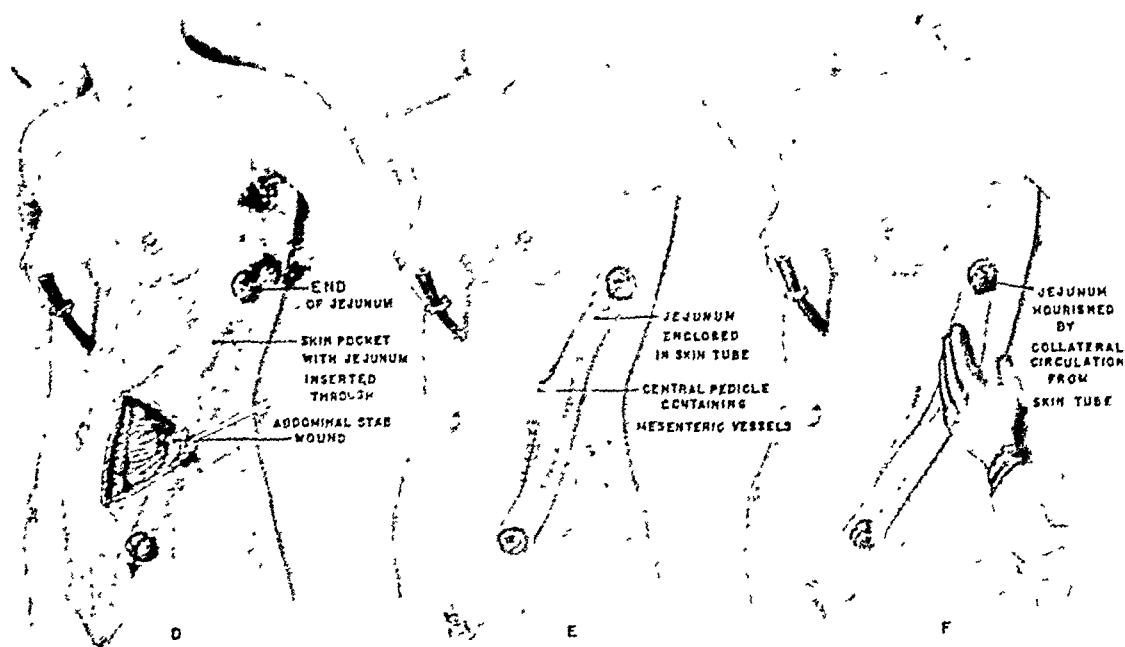


FIG. 6.—(D) Isolated intestine implanted in subcutaneous tunnel with mesenteric artery and vein passing through stab wound.  
(E) Central pedicle skin tube formed about isolated intestine.  
(F) Central pedicle and mesenteric vessels divided.

and pass through the first stab wound in the abdominal wall (Fig. 6-D). The original left rectus incision is closed. A period of at least a month is allowed to elapse for all edema and reaction about the implanted jejunum to subside before the second stage is carried out.

**STEP 2.**—The usual technic for the construction of a central pedicle skin tube has been employed (Fig. 6 E). In two of the cases to be reported only one-half of the tube was formed at a time. It is necessary to make a wide skin tube in order to be able to enclose the intestinal loop. The formation of the intestinal-skin tube is greatly facilitated if the diet of the patient is controlled and the amount of subcutaneous fat is kept at a minimum.

On two occasions it has been necessary to cover a part of the under surface of the tube itself with a split-thickness graft as it was not possible to obtain a wide enough tube to encircle the intestine properly. The use of such grafts on

\* In a recent case a segment of the central portion of the loop was resected as the intestinal loop is redundant when it is straightened. This procedure does not shorten the length of the loop as the length is actually determined by the mesenteric vessels rather than by the intestine itself.



the tube, however, is not recommended as it reduces the area through which collateral circulation is carried to the intestine when the mesenteric vessels are divided.

**STEP 3.**—Before completely dividing the central pedicle including the mesenteric vessels it is usually necessary to narrow the pedicle by further division of part of the surrounding skin. A rubber-shod intestinal clamp or a rubber band is used for temporary occlusion of the mesenteric vessels to aid in the development of collateral circulation. Temporary occlusion is continued several times a day for at least a week or until there is no change in the circulation of the skin tube after occlusion of the pedicle for 15 minutes. The mucosa of the jejunum is very sensitive to circulatory changes and will become moder-

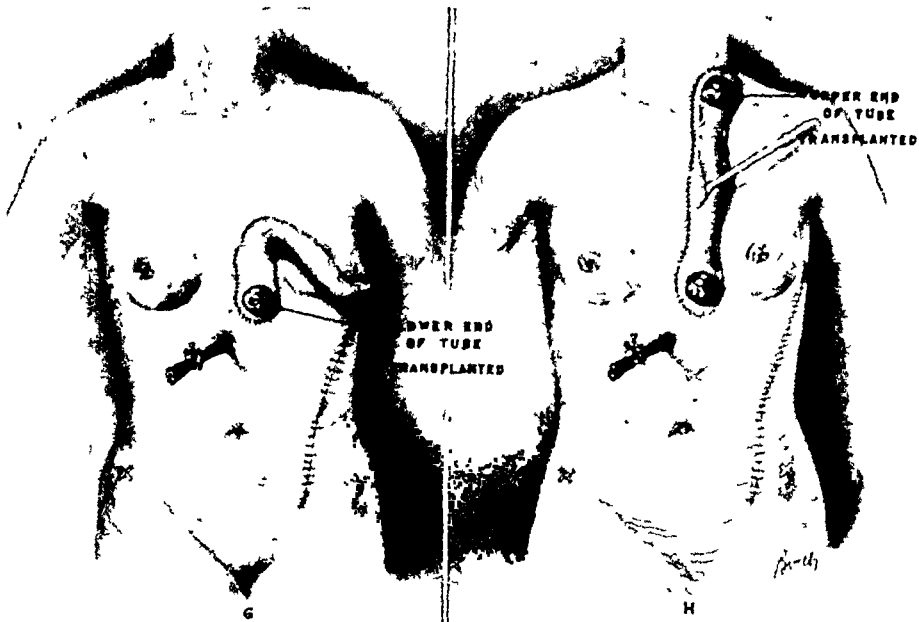


FIG. 7.—(G) Lower portion of intestinal-skin tube transplanted to left upper abdominal and lower thoracic region.

(H) Upper pedicle divided. Entire tube opened and implanted over left anterior chest.

ately cyanotic even after there is sufficient collateral circulation for the ultimate survival of the jejunum. After sufficient collateral circulation has developed the central pedicle is divided, the mesenteric vessels are ligated, and the defects on the tube and the abdominal wall are closed (Fig. 6 F). A month is then allowed for the disturbed circulation to become readjusted.

**STEP 4.**—The lower pedicle of the intestinal-skin tube is now temporarily occluded several times a day until circulation from the upper pedicle is sufficient to support the entire tube; it is then divided, usually in three stages, and transferred to the upper left abdominal region (Fig. 7 G). Care is used to implant the lower end of the tube high enough so that there will be adequate jejunum to reach easily to the cervical region when the upper portion of the tube is transferred. About one quarter of the lower end of the tube is implanted in the upper abdomen and chest wall in order to establish a wide pedicle to carry collateral circulation. A month or so later the upper pedicle is divided

and the entire tube is opened and implanted along the anterior chest wall. The upper end of the tube is placed along the anterior border of the left sternocleidomastoid muscle (Fig. 7 H).

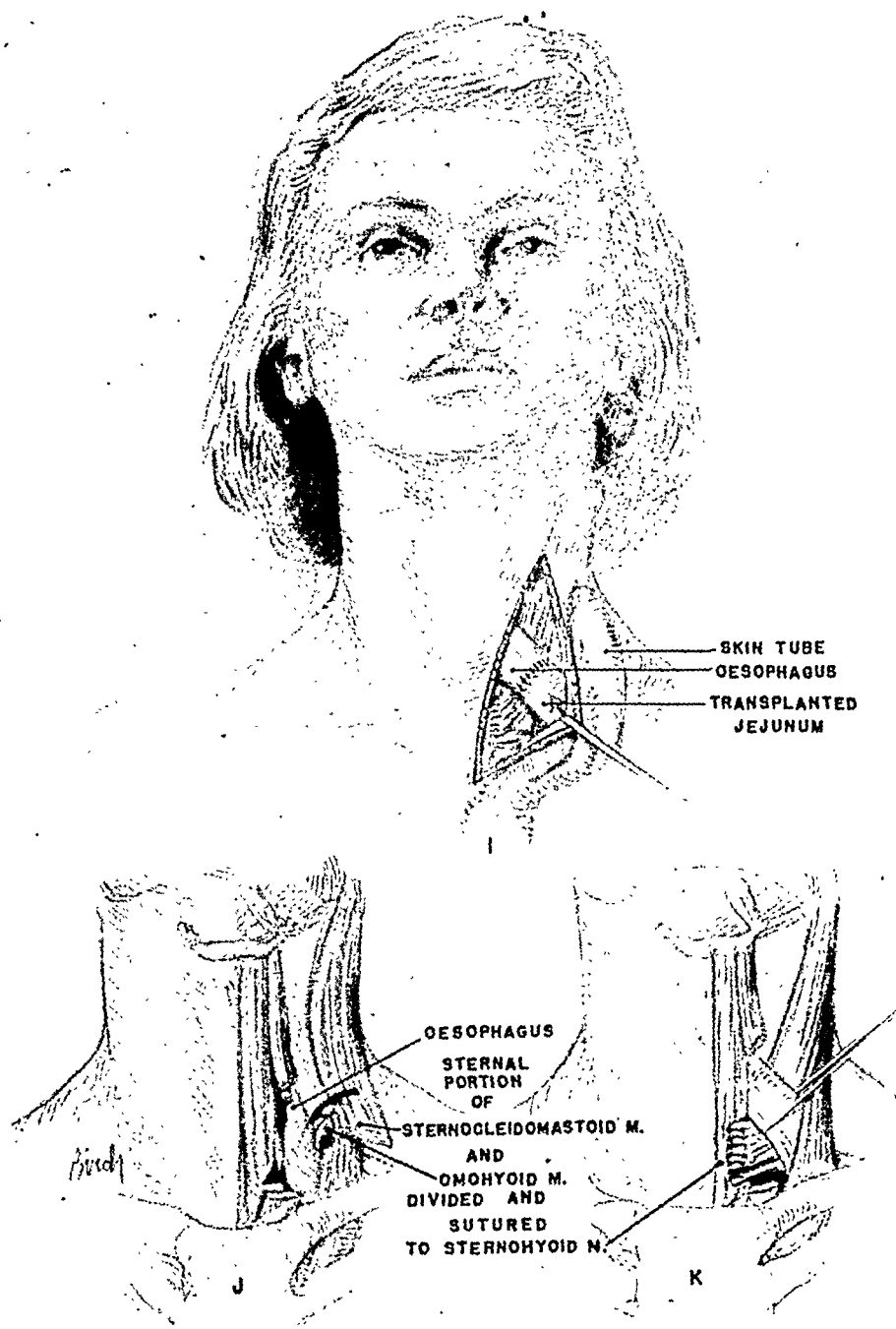


FIG. 8.—(I) End-to-side anastomosis between transplanted jejunum and mobilized cervical esophagus.

(J) and (K) Sternal portion of sternocleidomastoid muscle and omohyoid muscle passed beneath mobilized cervical esophagus and sutured to sternohyoid muscle.

STEP 5.—If the thoracic portion of the esophagus has not been removed as in the case of a benign stricture or congenital atresia, some type of lateral anastomosis should be performed in preference to dividing the esophagus and leaving a blind segment within the mediastinum. In one case reported in this

paper the end of the transplanted jejunum was anastomosed to the side of the cervical esophagus. Before the anastomosis was performed the cervical esophagus was explored and dissected from its usual position. The sternal portion of the sternocleidomastoid muscle and the omohyoid muscle were divided, passed beneath the esophagus, and sutured to the sternohyoid muscle. This maneuver held the esophagus in the superficial tissues and relieved tension on the suture line when the anastomosis was performed (Figs. 8 J and K). The area was packed with iodoform gauze so that the region became sealed off from the cervical and mediastinal spaces. One week later the incision was reopened and the end of the jejunal transplant anastomosed to the side of the esophagus (Fig. 8 I).

The lower end of the jejunal transplant has been anastomosed to the stomach in two patients. In the first there was sufficient length of the graft

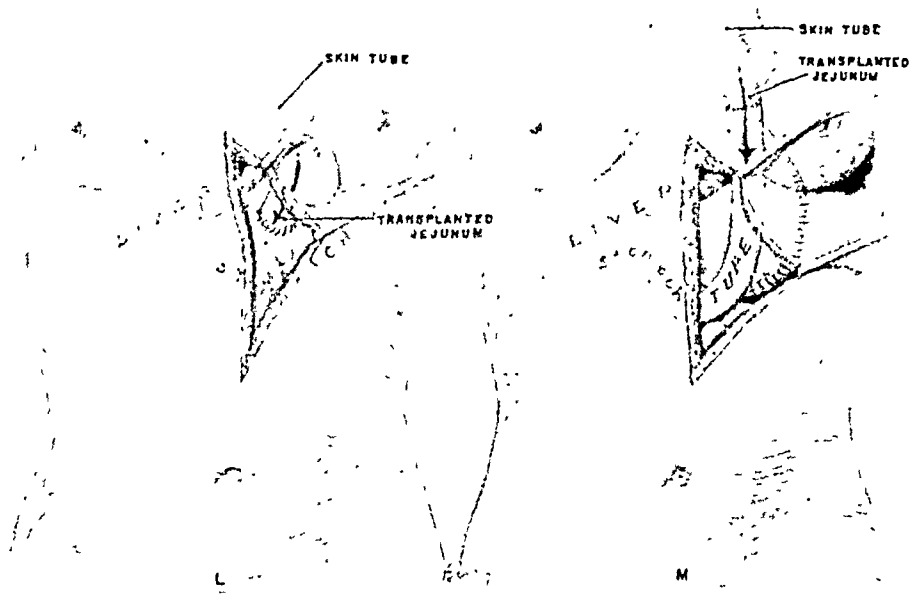


FIG. 9.—(L) End-to-side anastomosis between lower end of transplanted jejunum and side of stomach.

(M) Gastric tube formed from greater curvature and brought up anterior to costal margin for end-to-end anastomosis with lower end of transplanted jejunum.

below the costal margin to bring the end of the jejunum through a small upper left rectus incision and anastomose it directly into the side of the stomach.

In the second patient the lower portion of the graft was lost. After transplantation the graft extended from the cervical region down to the fifth interspace. A tube similar to the Beck-Jianu gastrostomy tube was formed from the greater curvature of the stomach and this was brought up over the costal margin and anastomosed to the lower end of the jejunal graft (Fig. 9 M).

A more detailed report of the clinical use of this method follows.

#### CASE REPORTS

**Case 1.**—The patient, E. R., was a 36-year-old white woman who had swallowed "several mouthfuls" of a caustic alkaline hair bleach in September, 1942. During the

following 20 months she had received fairly regular esophageal dilatations at weekly intervals. In spite of this treatment the scarred areas became denser and the patient had increasing difficulty in taking adequate nourishment. Roentgenography showed diffuse irregular constriction of the middle third of the esophagus with almost complete obstruction. The esophageal stenosis became so severe that gastrostomy was performed in January, 1944, and retrograde dilatations were attempted without success. Finally, in May it was decided to attempt the formation of an artificial antethoracic esophagus following the general outline of the method just described.

On May 18, 1944, a suitable segment of the upper jejunum was transplanted into the subcutaneous tissue. One month later the jejunal loop was enclosed in a skin tube with a central pedicle about the mesenteric vessels. As insufficient skin was obtained for complete encirclement of the lower third of the intestine, a split-thickness graft was used to complete the under surface of this portion of the tube. The tube was sufficiently long to allow the lower pedicle to be divided and implanted just below the left costal margin before the central pedicle was severed. This transfer was performed on August 3. On September 11 the central pedicle and the mesenteric vessels were divided and the lower one-fourth of the tube was implanted along the left border of the sternum.

After division of the mesenteric vessels the lower third of the jejunal tube that had been partially covered with a split-thickness graft failed to develop an adequate collateral circulation and sloughed. This mishap delayed the next procedure until December 23, when the upper pedicle was completely divided, brought up to a point one inch above the clavicle, and implanted along the left border of the sternum.

On February 5, 1945, the cervical esophagus was mobilized and placed in the subcutaneous region according to the method previously described under Step 5 in the preceding section. One week later the end of the jejunal graft was sutured into the side of the mobilized cervical esophagus. A fistula developed at the site of this anastomosis but closed spontaneously in three weeks (Fig. 10). The patient now had a satisfactory antethoracic esophagus lined with mucous membrane down to the level of the fifth costal cartilage, just above the costal margin; but owing to the loss of the lower third of the jejunal graft, an additional procedure was necessary to complete the channel into the stomach. On March 29 a Beck-Jianu gastric tube was formed from the greater curvature of the stomach and anastomosed to the lower end of the jejunal graft (Fig. 9 M). A fistula developed at this anastomosis, the closure of which required two subsequent operations.

There is still a moderate narrowing of the lumen at the gastrojejunal junction, but the patient now swallows liquids and soft foods. It is planned to dilate the area after healing is firm. When the patient swallows, the bolus of food passes rapidly through the oral segment of esophagus into the jejunal tube. The jejunum usually becomes moderately distended; then active peristaltic waves carry the contents into the gastric tube and on to the stomach. Occasionally reversed peristalsis causes a slight reflux into the esophagus and the patient has to swallow again. This reversal has never been great enough, however, to cause the patient to vomit or even to taste the regurgitated contents.

Case 2.—T. H., a white male infant with atresia of the esophagus and a tracheoesophi-



FIG. 10.—Photograph of patient E. R. after end-to-side anastomosis of transplanted jejunum to esophagus.

ageal fistula, was operated upon on September 8, 1942, when five days old, by Dr. Alfred Blalock. The blind oral end of the esophagus was exteriorized above the left clavicle and the abdominal portion of the esophagus delivered through an upper left rectus incision to serve as a gastrostomy.

On April 22, 1943, an unsuccessful one-stage attempt was made to form a skin-tube antethoracic esophagus of the Bircher type.

The present method was begun on October 28, 1943, when the child was 13 months old. In spite of the extremely poor condition of the infant and numerous unrelated complications such as osteomyelitis of the humerus, dislocation of the hip, otitis media, anal stenosis, and numerous attacks of diarrhea, a satisfactory intestinal-skin tube was formed, transferred to the anterior chest wall, and anastomosed to the stomach and esophagus (Figs. 11 to 15). A fistula developed at the site of the esophagojejunal anastomosis, and

before this was closed the patient died on July 2, 1945, of a pyocyanus septicemia. All of the operative areas were healed at this time. At autopsy there was no evidence of infection about any portion of the transplanted intestinal skin tube.

**Case 3.**—R. C., a 25-year-old white woman with an impermeable stricture of the esophagus due to the ingestion of lye, now has a complete intestinal-skin tube and the mesenteric vessels have been divided. At present the tube is ready to be transferred to the anterior chest wall (Fig. 16).

#### DISCUSSION

Although primary anastomoses are being performed more frequently now than formerly after resections of malignant esophageal lesions and for congenital atresia, there are still numerous cases in which the oral end of the esophagus must be exteriorized and some form of secondary antethoracic construction carried out. Such esophageal reconstructions are also indicated in certain cases of benign impermeable strictures if dilatations have failed.

Although numerous types of antethoracic esophageal reconstruction have been devised, relatively few com-



FIG. 11.—Patient T. H. following first stage, with isolated jejunal loop implanted in subcutaneous tunnel.

pleted cases by any method have been reported. Most of the technics are laborious and uncertain. Some, such as the gastroesophagoplasty, have an excessive mortality rate (66.3 per cent).<sup>7</sup>

The jejunodermato-esophagoplasty of Lexer has been the most popular type of reconstruction but has the disadvantage of being formed largely of an inactive skin tube which, in certain persons, may contain enough hair to cause



FIG. 12.—Lower half of central pedicle skin tube formed.



FIG. 13.—Completed intestinal-skin tube with intact central pedicle.

FIG. 14.—Lower pedicle divided and implanted in left upper quadrant. In this patient the mesenteric vessels and central pedicle were not divided until after this stage.

obstructive signs. The three anastomoses—the esophagus to the skin tube, the skin tube to the jejunum, and the jejunum to the stomach—all provide sites for the formation of fistulae and subsequent stenosis. The jejuno-esophagoplasty of Roux and Herzen has been popularized by Yudin's<sup>8</sup> 11 successful cases. Not infrequently, however, the arrangement of the mesenteric vessels is such that sufficient viable jejunum cannot be mobilized to reach to the cervical region. Ochsner and Owens<sup>7</sup> reported gangrene of the jejunal loop occurring in 22 per cent of the patients operated upon by this method.



FIG. 15.—Intestinal-skin tube transplanted to left anterior chest wall.

Other methods that have been used include the transfer of gastric tubes, migration of the entire stomach, or transplantation of a segment of the colon. In all of the methods thus far reported the transplanted portions of the alimentary tract have depended upon the original mesenteric vascular system for their blood supply.

The use of a segment of jejunum as a free graft eliminates many of the major objections to the previous methods in that it provides a channel lined with mucous membrane which has active peristalsis and which can be anastomosed directly to gastric mucosa with little fear of subsequent ulceration. Our method has the disadvantages of being time-consuming, and of requiring multiple operations. The first step, however, is the only really major operative procedure and carries only the risk inherent in any anastomosis of the small intestine. Most of the steps are minor plastic operations which expose the

patient to very little risk and discomfort. Although our experience with this method has been limited, we believe it has certain advantages which justify a preliminary report.

#### SUMMARY

A new method for constructing an artificial antethoracic esophagus is described. This method was developed in experimental animals and has been used in the treatment of three patients with benign esophageal lesions. In this

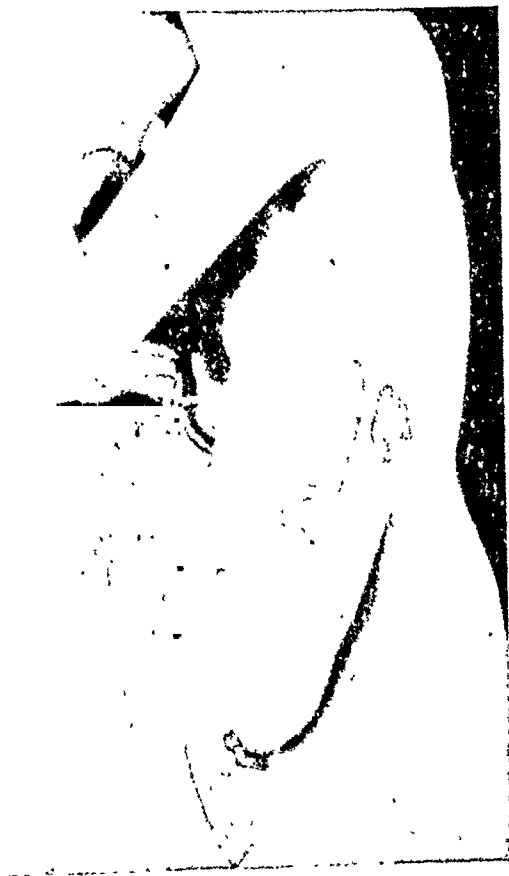


FIG. 16.—Patient R. C., with intestinal-skin tube formed. Central pedicle and mesenteric vessels divided.

method an isolated segment of jejunum enclosed in a skin tube is transferred to the anterior chest wall to serve as a channel between the cervical esophagus and the stomach.

The use of a free jejunal graft allows the intestine to be transplanted wherever needed unrestricted by an attached mesentery. It provides a channel which is completely lined with mucous membrane and which has active peristalsis to aid in transporting the swallowed bolus to the stomach.

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DISCUSSION.—DR. WILLIAM F. RHINHOFF, Jr., Baltimore, Maryland: I personally wish to extend my sincere congratulations to Drs. Longmire and Ravitch on their most interesting fundamental contribution to the difficult problem of antethoracic esophagoplasty. I have recently made a rather complete review of the literature on the subject of esophageal surgery and have been impressed with the many different methods of reconstruction of the esophagus that have been employed in the past. Although alluring to the mechanical sense, the great majority of these procedures have been unsatisfactory for one reason or another. In my opinion the method of Longmire and Ravitch would seem to be the most satisfactory yet to be described.

The surgeon who deals with the problem of antethoracic esophagoplasty must be one of great versatility as well as virtuosity. However, different problems from a surgical technical standpoint are posed by different lesions of the esophagus. The time element must be taken into consideration particularly when one is dealing with malignant tumors of the esophagus in elderly people. Thus, the minimal number of operative procedures is to be preferred to one requiring multiple stages. It would seem that the ideal to be aspired to in the treatment of carcinoma of the esophagus would involve not more than two stages or operative procedures, with the reconstructed esophagus ultimately lying in the thoracic cavity in the bed of the resected esophagus. At the same time the reconstructed esophagus should consist of a tube approximating the normal esophagus in size.

In 1942, the intrathoracic transplantation of the jejunum was, I believe, accomplished for the first time and reported with other cases at the meeting of the American Association for Thoracic Surgery in 1944.\* Mobilization of the jejunum was first suggested by Tavel, before 1900, in order to free a short loop of the jejunum to effect a permanent gastrostomy. In 1904, Wulstein proposed more extensive mobilization of the jejunum, sufficient to transplant a free loop subcutaneously extending from the abdomen to the pharynx. The operation was performed only on the cadaver until 1907, when Roux transplanted such a loop in a child suffering from lye stricture. Whether or not the final anastomosis was made between the jejunum and esophagus in this case could not be determined from Roux's report. Furthermore the ultimate result as to the success of the procedure was never published which, to my mind, cast some doubt on the probable end-result. Roux recommended division of the first five branches of the superior mesenteric artery, *i. e.*, the vasa recta, jejunalis, division of the jejunum just distal to Treitz's ligament, followed by jejunojejunostomy between the proximal loop and the aboral portion of the distal loop. The mobilized loop of jejunum was then transplanted, as suggested by Wulstein, subcutaneously at once. This method, the Wulstein-Roux, fell into disrepute because such extensive mobilization of the jejunum necessary to reach from the posterior peritoneal wall, out and over the costal margin, up and along the thoracic cage to the level of the neck above the clavicle, resulted in a high percentage of gangrene of the oral end of the loop. It was realized that far less mobilization of the jejunum would be necessary if the freed loop was brought up transthoracically in the bed of the resected esophagus in order to traverse the distance from Treitz's ligament

\* *Jour. Thoracic Surgery*, Vol. 13, October, 1944, No. 5

to the dome of the thoracic cavity, a distance of 30 cm. It was found necessary to divide only three of the vasa recta jejunalis, the second, third and fourth, to obtain a sufficient length of intestine, 40 cm., to reach transthoracically to the dome of the chest cavity. Thus, the danger of jeopardizing the blood flow to the oral end of the mobilized loop is very much lessened.

I should like to report a case in which this procedure has been successfully carried out and which is, I believe, the first time such a transthoracic esophagojejunostomy has been done for carcinoma of the esophagus.

**Case Report.**—M. C., age 49, was referred to me by Dr. J. C. Dickinson, of Tampa, Florida. An early diagnosis had been made of a carcinoma of the esophagus at the level of the arch of the aorta. At the first stage the jejunum was mobilized by dividing the second, third and fourth vasa recta jejunalis. The intestine was divided about 6 cm. from Treit's ligament. The first vasa recta jejunalis was preserved. A jejunojejunostomy was then performed, end-to-side, between the open end of the proximal loop just distal to Treit's ligament and the aboral portion of the mobilized loop. The oral end of the mobilized loop was then closed with interrupted silk sutures and this end was fixed in the esophageal hiatus. The abdomen was closed. Three days later the chest was opened by resecting the seventh rib; the esophagus was resected, including a safe margin above the growth. The upper end of the esophagus was then brought out lateral to the aortic arch. An end-to-end anastomosis was performed between the jejunum and the esophagus. The fixation of the jejunum into the esophageal hiatus made it less difficult to locate this end when the chest was opened. There was no tension. The jejunum was brought out through the esophageal hiatus without the slightest difficulty. The tendinous portion of the diaphragm bordering this esophageal hiatus was incised to allow more freedom for drawing the jejunum into the chest. It has been a period of ten months, and this patient has remained perfectly well, being able to swallow ordinary meals; no special type of food or diet has been necessary.

DR. ALTON OCHSNER, New Orleans, La.: This method which Doctor Longmire has described is certainly ingenious. After an experience of six cases which Doctor Owens and I have had, using a jejunodermato-esophagoplasty, I am thoroughly convinced that this is much preferable to the one we used. The procedure we used is fraught with a good many technical difficulties. In our first case we performed 15 operative procedures. One thing Doctor Owens, who is our plastic surgeon, insisted upon is that the cervical portion of the operation not be done until after the skin tube had been formed. I think this is an important point because of the danger of interference with healing due to the cervical esophageal fistula. A great advantage of Doctor Longmire's procedure is that it produces a mucous membrane-lined tube which has active peristalsis. On the other hand, patients with a jejunodermato-anterothoracic esophagoplasty can swallow well. Peristalsis is not necessary. They were able to swallow through propulsive force of the pharyngeal muscles.

# EXPERIENCES IN SUBTOTAL RESECTION OF THE PANCREAS IN HYPOGLYCEMIA\*

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SINCE the fundamental suggestion of Harris<sup>1</sup> and the first case report of Wilder,<sup>2</sup> the importance of islet tumors of the pancreas as a cause of hypoglycemia has increased with added experience. In a report, in 1944, Whipple<sup>3</sup> collected 149 cases from the literature, including his own, where small adenomas of the islet tissue or carcinoma arising from the same cells had been removed surgically, with cure or great improvement of the disturbed sugar metabolism. It has been learned from experience that the tumors may be single or multiple, they may occur in the head of the pancreas as well as in the tail, and they also are occasionally found in aberrant pancreatic tissue or in an accessory pancreas. Hyperplasia of the duct cells of the islands of Langerhans may also be associated with hypoglycemia.

The symptoms of hypoglycemia are numerous but, as Whipple has pointed out, they arrange themselves rather definitely into three categories: (1) During an attack, the fasting blood sugar is below 50 mg. per cent. (2) The patient may experience a great variety of nervous symptoms varying from weakness or fainting and muscular irritability to amnesia or tonic or clonic convulsions. (3) During an attack, the administration of large amounts of sugar relieves the symptoms.

Among the causes of hypoglycemia in any given patient it is extremely important to consider the possibility of lesions of other organs and glands which are known to influence sugar metabolism as the liver, adrenal, hypophysis, and thyroid. The symptoms of hypoglycemia may also be found in patients with an unstable nervous system, and here the importance of Whipple's triad is helpful in differential diagnosis. The purely dietary management of hypoglycemia<sup>4</sup> should always be tried before surgery is resorted to.

Careful selection of cases by exclusion, as far as possible, of other causes of hypoglycemia leads to an indication for surgical removal of the islet cell tumor. This program has resulted in many cures, with a surgical mortality of about 15 per cent. The causes of the failures frequently have been discovered at a subsequent operation or at autopsy where a small adenoma has been found in the head of the pancreas or buried in its substance, or occasionally found in an accessory pancreas or in aberrant pancreatic tissue.

There is, however, another small group of patients who have the classical symptoms of hypoglycemia presumably due to an islet tumor of the pancreas

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but in whom no tumor is found after careful exposure of all available parts of the pancreas at operation. The purpose of this paper is to discuss this problem, particularly from the viewpoint of the advisability of performing a subtotal pancreatectomy at the time of exploration.

In 1935, I<sup>5</sup> reported a typical example of this particular group where a patient having a very severe hypoglycemia with convulsions was operated upon and in the absence of a tumor of the pancreas, 49 grams of pancreas was resected, with complete relief of symptoms up to the present time (Fig. 1). In that report, the literature was carefully reviewed and all patients having a small or large portion of the pancreas removed for hypoglycemia were studied. It was found that in the patients answering the criteria necessary for surgical intervention 18 had a small amount of the tail of the pancreas (8 to 28 Gm.) removed with very little effect on the course of their illness. On the other hand, 14 patients who had 40 Gm. or more of pancreas removed were completely relieved of their symptoms, with an operative mortality of one patient.

Since that report,<sup>5</sup> we have had the opportunity of operating upon two additional patients with hypoglycemia where no adenoma was found on careful examination of the pancreas and a massive resection of the pancreas was carried out. A review of the literature up to a recent date has added a number of other cases falling into this group so that the records of 36 patients are now available for review.

TABLE I

36 CASES WITH HYPOGLYCEMIA. AT OPERATION NO LESION OF THE PANCREAS WAS FOUND.  
MASSIVE RESECTION OF THE PANCREAS PERFORMED.

	No. of Cases	Cured	Slight or No Improvement	Died
Adenoma*.....	5	5		
Hyperplasia of islets.....	6	3	3	
Normal pancreas histology.....	25	15	8	2
	36	23 (63%)	11 (31%)	2 (6%)

\* In five patients, an adenoma of the islet tissue was found in the resected portion of the pancreas, and all five of these patients completely recovered.

In a patient reported by Frantz,<sup>8</sup> two previous operations had been performed and an adenoma removed at each operation before Whipple undertook the third operation because of persistence of symptoms. He resected the body and a portion of the head of the pancreas and discovered five small adenomas in the resected tissue. Priestley, Comfort, and Radcliffe,<sup>7</sup> being unfavorably impressed by the poor result obtained on a patient, operated upon by Rynearson, by massive resection of the pancreas, performed a complete pancreatectomy on a patient and found an adenoma 8 x 5 x 5 mm. in the head of the pancreas. The patient was cured of the symptoms of hypoglycemia and required 66 units of insulin a day to control the diabetes.

There were six patients in whom a massive resection of the pancreas was performed and a study of the resected tissue revealed hyperplasia of the islet tissue.

TABLE II

SUBTOTAL REMOVAL OF APPARENTLY NORMAL PANCREAS.  
SMALL ADENOMA FOUND IN RESECTED PANCREAS

Author	Publication	Age	Whipple Triad		Operation	Pathology	Result
1. Frantz, V. K.	Ann. Surg., 119; No. 6, 824, June, 1944	16 yrs.	+		1st by McDonald Feb., 1942. Adenoma removed 2nd—May, 1942. Only temporary improvement 3rd by Whipple July, 1942. Body and portion of head removed. 5 adenomas found	Adenoma	Cured
2. Frantz, V. K.	Ann. Surg., 119; No. 6, 824, June, 1944		+		Tail and half of body removed by Dr. St. John. Small pancreas	2 small adenomas	Cured
3. Priestley, J. T., Comfort, M. W., and Radcliffe, J.	Ann. Surg., 119; 211, Feb., 1944		+		Total pancreatectomy	Small adenoma 8x5x5 mm. in head	Diabetic. 66 units of insulin necessary
4. Wangensteen, O.	Minn. Med., 18; 265, 1935	37 yrs.	+		Two-thirds pancreas removed	Adeno- carcinoma	Cured 3 years
5. Engle, L. P.	Personal com- munication to A. O. Whipple	38 yrs.	+		Subtotal removal	Adenoma in tail	Well 10 months

TABLE III

SUBTOTAL REMOVAL OF PANCREAS. NO TUMOR FOUND. DEFINITE HYPERPLASIA OF THE ISLETS OR SMALL ADENOMA.  
FOUND IN RESECTED PANCREAS

Author	Publication	Age	Duration Symptoms	Blood Sugar	Operation	Pathology	Result
1. Simon, H. E.	So. Surg., 3; 199, 1934	26 yrs.	3.5 months. Unconscious- ness	51 mg. %	60 grams pancreas removed	Hyperplasia of islets	Well 3 years. Died from ac- cident
2. McCaughan, J. L., and Brown, G. O.	Ann. Surg., 105; 354, 1937	20 yrs.	Convulsions	70 mg. %	35 grams removed	Hyperplasia of islets	Recur- rent symp- toms
3. H. Harris (Drennan)	So. Surg., 3; 199, 1934	27 yrs.	4 months	65 mg.			Unim- proved 4 years
4. Maxeiner, S. R., and Bundy, H. E.	Surgery, 18; No. 2, 171, 1945		Hypoglycemia. Nervousness		45 grams removed	Hyperplasia of islets re- sembling minute adenoma	Cured
5. Leriche, R., and Schneider, H.	Presse Med., 49; 561, May 28, 1941	42 yrs.	Hypogly- cemia. Nervousness	60 mg. %	10-cm.-long long piece of tail and body. Op. 1937	Hyperplasia of islet cells	Cured 3 years
6. Frantz, V. K.	Ann. Surg., 119; No. 6 June, 1944			Whipple triad	One-half pancreas removed. Op. by Whipple	Hyperplasia of islets	No im- prove- ment

# PANCREATECTOMY IN HYPOGLYCEMIA

TABLE IV

SUBTOTAL RESECTION OF PANCREAS, PANCREAS FAIRLY NORMAL, NO TUMOR FOUND				
Author	Publication	Age	Duration Symptom <sup>4</sup>	Whipple Triad
1. Harris, S. (Taylor)	J. A. M. A., 100; 321, 1933	20 yrs.	2 yrs.	+
2. Graham, E. A., and Hartman, H. F.	Surg., Gynec., & Obst., 59; 474, 1934	1 yr.	9 mos.	+
3. Harris, S. (Drennan)	South Surg., 3; 109, 1934	32 yrs.	?	+
4. Thonason, G.	West. J. Surg., 43; 185-192, 1935	13 yrs.	3 yrs.	+
5. Reinhoff, W. F., and Lewis, Dean	Bull. Johns Hopkins Hosp., 386, 1934	39 yrs.	18 mos.	+
6. McCaughan, J. M., and Brown, G. O.	Ann. Surg., 105; 354, 1937	26 yrs.	24 yrs.	+
7. Engel, L. P.	Personal com- munication to Whipple	55 yrs.		+
8. Womack, L. A., and Cole, W. H.	Ann. Surg., 105; 370, 1937	36 yrs.	1 yrs.	+
9. Womack, L. A., and Cole, W. H.	Ann. Surg., 105; 370, 1937	26 yrs.	3 yrs.	+
10. Clarke, J. M.	Australian & New Zealand J. Surg., 8; 66-73, 1938			+
11. Engel, L.	Personal communi- cation			+

Result

Well, 6 yrs.

Symptom free 1 yrs.; mentally deficient

Symptom-free 1 yrs.

Symptom-free 4 yrs.

Died first postoperative day

Recurrent symptoms

Symptom-free 7 yrs

Cured

Cured

Cured

Cured but low blood sugar

TABLE IV—Continued

Author	Publication	Age	Duration of Symptoms	Whipple Triad	Operation	Pathology	Result
12. Womack, L. A.	Personal communication			+			No improvement
13. Carrol, W. C.	Minnesota Med., 20; 229, 1937	30 yrs.	9 mos.	+			Improved; nervous
14. Berry, J. G.	Brit. Jour. Surg., 23-51, July, 1935	28 yrs.	14 yrs.	+	Tail and part of body removed, 28 grs. logically	Normal histologically	Cured 8 mos.
15. Wagner, W.	Canad. Med. A. Jour., 40-49, July, 1941	20 yrs.		+	Body, tail and spleen by R. Graham, Nov., 1938	Islets were numerous Cells varied	Cured 6 mos.
16. Rynearson, E. H., and Walters, W.	Proc. Staff Meet. Mayo Clinic, 13; 728, Nov. 16, 1938	32 yrs.	10 yrs.	Con- vul- sions	1st—Holman. One-half pan- creas removed. 2nd—Judd. Nodule removed 3rd—Authors. Normal		No im- prove- ment
17. Frantz (1) (op. by Dr. A. Whipple)	Ann. Surg., 119; No. 6, 824, June, 1944		Hypo- gly- cemia	Blood sugar below 42	One-half pan- creas removed the ducts	Hyper- plasma	Blood sugar rose from 42 to 46
18. Frantz (2)	Ann. Surg., 119; No. 6, 824, June, 1944		Hypo- gly- cemia	Blood sugar below 50	One-half pan- creas removed	Normal	No im- prove- ment
19. McClure, Roy, and Brush, B. E. (1)	Ann. Surg., 120; 750, Nov. 1944	19 yrs.	11 mos. Weakness, sweating, tremor	55 mg. %	Two-thirds pancreas removed	Normal	Cured 2 mos.
20. McClure, Roy, and Brush, B. E. (2)	Ann. Surg., 120; 750, Nov., 1944	43 yrs.	13 yrs. Weakness, nervousness, excessive hunger	60 mg. %	Five-sixths pancreas removed	Normal	Cured 2 yrs.

TABLE IV—Continued

Author	Publication	Age	Symptoms Duration	Blood Sugar	Operation	Pathology	Result
21. Wechsler, L. S., and Garloch, J. H.	J. Mt. Sinai Hosp., 10; 70-4, Jan.-Feb., 1944	36 yrs.	Weakness, nervousness	20 mg. %	Body and tail removed	Normal	No im- prove- ment. Bl. sugar 30. 2 yrs. after
22. David, V. C., and Woodyatt, R. T.	Surgery, 8; 2, 212-224, Aug., 1940	21 yrs.	Clonic and tonic con- vulsions	Below 60 mg. %	Body and tail, 48 grams, re- moved. May, 1938	Normal	Cured 7 yrs.
23. David, V. C., and Woodyatt, R. T.	See text.	40 yrs.	Nervous- ness, con- vulsions, worry. 3 yrs.	Below 60 mg. %	Body and tail of pancreas (38 grams) and spleen removed. Mar. 18, 1941	Normal	Recovery and cure, except some diarrhea. Sugar tolerance normal
24. David, V. C., Woodyatt, R. T., and Campbell, L.	See text		Unconscious- ness, convul- sions, sweat- ing, mental symptoms	20 mg. %	1st op. Body and tail of pancreas (28 grams) and spleen removed. Pancreas small and atrophic. 2nd op. All but 3-4 grams pancreas removed	Normal	No im- prove- ment
25. Barnes, J. A.	New England J. Med., 213; 225, Aug. 1, 1935	35 yrs.	Hypogly- cemia, nervousness, 18 months	35 mg. %	2 inches pancreas removed	Normal	Died 3rd day. Bl. sugar after 60 grams glucose
*26. Harris, S., and Drennan	South. Surg., 3; 199, 1934	27 yrs.	Convulsions 4 months	65 mg. %	One-half body and tail removed		Unim- proved 4 yrs.

\* Questionable case due to relatively high blood sugar.



Only three of these patients were relieved of their symptoms and two of these have been followed three years.

The most interesting group consists of 25 patients whose resected pancreas was normal histologically.

Following operation, two of these patients died, six had no improvement, and 15 (60 per cent) were cured of their symptoms of hypoglycemia. Eight of the patients have been followed for two to seven years. Ryncarson and Walters had a very disappointing result in a patient, one-half of whose pancreas had been previously removed by Holman and had been subsequently explored by Judd. At the third operation, all of the pancreas except a small piece near the entrance of the duct into the duodenum was removed without improvement to the patient. Our third patient to be reported had a similar unfavorable result after almost complete pancreatectomy. In contrast to the unfavorable results recorded, there still remain 60 per cent of the patients who were cured of their symptoms of hypoglycemia by massive resection of the pancreas where grossly and histologically the pancreas appeared normal. I can offer very little logic as to why this should be true but faced with a critically sick patient where hyperinsulinism appears to be responsible for the hypoglycemic state and upon careful exploration of the pancreas no tumor is found, I am impressed with the advisability of resecting a major portion of the pancreas. Under such conditions, 23 of the 36 patients reviewed in this study were cured.

The report of the two additional cases of our own offer a marked contrast to each other. The first patient was almost a replica of our previously reported case. A typical hypoglycemia with convulsive seizures with a fasting blood sugar of 50 mg. per cent and relieved by administration of sugar was completely relieved of her symptoms (with the exception of a functional colitis) by removal of 45 Gm. of the tail and body of her pancreas and her spleen. Histologically the pancreas was normal. (Fig. 2)

The third patient was the most seriously ill of the three, requiring supplementary feedings of glucose every four hours and with a blood sugar during an attack of 20 mg. per cent or so low it was unreadable. This patient had the appearance of an hypohypophyseal dyscrasia but roentgenograms of the sella showed but slight thinning of the postclinoids and roentgenotherapy of the region of the hypophysis gave no relief. At operation, the liver and adrenals were normal and there was no evidence of an accessory pancreas. The pancreas was small and atrophic and when removed to a point just to the right of the superior mesenteric vessels, the resected specimen weighed only 28 Gm. Histologically, the resected pancreas was normal (Fig. 2). The patient recovered well from her operation but there was little or no change in her clinical picture or in her sugar metabolism. At this stage, Dr. Leo Campbell decided to give the patient Alloxan parenterally, based on the necrotizing effect it had shown on the islet tissue in animals and its use by Brunschwig in a patient with a carcinoma of the islet tissue who had hypoglycemia. High doses were given with some reluctance without effect.

Six months having elapsed and the patient being in much the same condition, reoperation was decided upon, at which time, with some difficulty, the remainder of the pancreas was largely removed leaving perhaps 3 to 5 Gm. closely adherent to the duodenum. This tissue was also normal histologically and contained no tumor tissue. Following this operation, the patient required less sugar for a week and at one time had sugar in the urine at ten drops of reducing agent. However, in a few days the *status quo ante* was resumed and the patient today is as much of a problem as ever.

#### CASE REPORTS

**Case 1.**—Miss W. N., age 40, was first admitted to the Presbyterian Hospital in December, 1938, on Dr. Rollin T. Woodyatt's service with the following complaints: (1) Twitching and shaking of the lower extremities for two weeks; (2) attacks of nervousness and tenseness accompanied by loss of strength beginning two weeks previous to admission; (3) anorexia for three years; (4) loss of weight, ten pounds; and (5) excessive worry.

The blood sugar was 50 mg. per cent at its lowest point. Her symptoms were relieved by the administration of large amounts of glucose. Her general examination, roentgenograms of the gastro-intestinal tract, metabolic rate, and blood chemistry were normal, with the exception of her glucose tolerance. A diagnosis of spontaneous hypoglycemia was made. Between 1938 and 1941 she was hospitalized five times, and given treatment. In March, 1941, she returned for surgical treatment, inasmuch as her condition had become worse.

At operation, March 18, 1941, under gas-ether anesthesia, through a transverse upper abdominal incision, the pancreas was found to be rather small. It was thoroughly explored, including reflexion of the duodenum to the left so that the head could be thoroughly examined, and no tumor was found. A resection of the body and tail of the pancreas was done, removing 38 Gm. of pancreas, to a point somewhat to the right of the superior mesenteric vessels and leaving a piece of pancreas in the concavity of the duodenum the size of a walnut. It was estimated that five-sixths of the pancreas was removed. One cigarette drain was left after bringing the cut surfaces of the pancreas together by interrupted silk sutures. The patient recovered easily from her operation and since that time to the present has had no return of her symptoms of hypoglycemia and has a normal blood sugar and glucose tolerance. She does complain of attacks of diarrhea which are controlled by a bland diet. There is no fat indigestion. The pathologic examination of the resected pancreas revealed no adenoma of the islet tissue. The islet tissue appeared normal.

**Case 2.**—Mrs. B. L., age 47, was a patient of Drs. Leo Campbell and Rollin T. Woodyatt. For a number of years she had been drowsy much of the time, sweated easily, and had headaches. Three years ago she went through the menopause. Two years ago she came to the Presbyterian Hospital in coma and was revived by intravenous glucose injection. She had to be awakened each morning at 5:00 A.M. to be given sweetened fruit juice to prevent coma. A year ago her blood sugar was 40 mg. per cent, and she began to have convulsions and became irrational unless given frequent feedings of sugar.

On examination, her metabolic rates were from  $-5$  to  $-10$ . The roentgenograms of her sella showed some thinning of the postclinoid processes. Her optic disks were normal. Her fasting blood sugar was 30 mg. per cent. She was given roentgenotherapy (3,000 R.) over the hypophysis without result.

On May 26, 1944, she was explored through an upper transverse abdominal incision, under gas-ether anesthesia.

General exploration of the abdominal contents revealed no particular pathology. The pancreas was smaller than normal and uniformly firm. Thorough examination of

the tail, body, and head, after rotating the duodenum medially, revealed no tumor. All of the pancreas to the left of the superior mesenteric vessels was removed. It weighed only 28 Gm. The spleen was normal and was also removed due to ligation of the splenic vessels in removal of the pancreas. The cut-surface of the pancreas was repaired by interrupted silk. One Penrose drain was left.

The pathologic examination of the pancreas showed no abnormalities in the islet tissue.

A few days after operation, the blood sugar was 50 mg. per cent. On one examination there was a trace of sugar in the urine with ten drops of reducing agent, but in a short time the patient was in the same condition as before operation and required feedings of sugar every four hours to keep her out of coma and convulsions. One month later, Doctor Campbell began treating her with Alloxan. Alloxan is the ureid of mesoxalic acid. It is given in 1 per cent solution at the rate of 3 cc. per minute. In rabbits and dogs not only are the islands of Langerhans necrosed by its use but transient degeneration of the kidney tubules and of the liver is also observed. In animals the dosage is 100-150 mg. of Alloxan per kilogram body weight. In dogs treated with Alloxan there ensues a short period of hyperglycemia followed by a severe hypoglycemia, with convulsions.

Treatment of this patient by Alloxan was given June 29 and 30 and July 1, 1944, giving her 150 mg. per kilo of body weight, or a total of 450 mg. Not only was there no change in the hypoglycemic state but her reactions were more severe and frequent.

Adrenal cortex (Wilson's crude) 3 cc. every six hours was given for three weeks without any evident effect.

On November 17, 18 and 19, 1944, she was given Alloxan, 250 mg. per kilo body weight. Seven days later the blood sugar was as low as 30 mg. per cent and she was still having severe reactions. There was no evidence of liver or kidney damage.

On January 24, 25 and 26, 1945, Alloxan was given in 250 mg. doses per kilo of body weight without effect. The N. P. N. of the blood remained normal but the Hanger test for liver function became weakly positive but became negative after a week. The prothrombin was 90 per cent.

On March 1, 1945, she was given 2 cc. of Armour's Growth Hormone (pituitary diabetagenic) and this was continued for nearly three weeks without demonstrable effect.

From April 7, 1945 to May 10, 1945 she was given 9 gr. of desiccated thyroid a day without influence on the hypoglycemic attacks. This was given because permanent diabetes was produced by Housay in dogs with transient diabetes from partial pancreatectomy when sustained large doses of thyroid was administered.

From May 10 to July 8, 1945, the patient was given 15 cc. daily of crude liver (1 cc. = 1 unit) because hypoglycemia glycosuria has been reported in individuals receiving large doses of the crude extract. This medication produced no change in the hypoglycemic attacks in this patient.

Because of the continuing desperate condition of the patient, it was decided to reoperate upon her. On July 21, 1945, under gas-ether anesthesia, a transverse incision was made above the umbilicus. Due to the marked adiposity of the patient and obliterating adhesions from the previous operation, the mechanical problem was tedious, but the pancreas was separated from the superior mesenteric vessels and portal vein and all of it was removed but a very small portion next to the duodenum where the pancreatic duct entered the duodenum. No adenoma was found grossly or histologically in the resected portion and the islet tissue appeared normal or slightly hyperplastic in spite of the large doses of Alloxan the patient had received.

The abdomen was closed with silk technic with one Penrose drain, and the patient recovered without serious complication. Unfortunately, her hypoglycemia persists and the subtotal removal of her pancreas has had no effect on the course of her disease as she now requires frequent feedings of glucose to prevent the symptoms of syncope and convulsions.

She is now being given a crude oil extract of the hog adrenal cortex, which is reported to contain compound "E," which was discovered by Kendall and shown to produce hyperglycemia in animals.

### CONCLUSIONS

In patients with symptoms of serious hypoglycemia where surgical intervention is indicated and upon careful examination of the pancreas at operation no pathology is found, it appears indicated to undertake a massive resection of the pancreas at that time.

Thirty-six patients in this category were so treated with 23 recoveries from their symptoms, and two deaths.

In 25 patients, the resected pancreas showed no pathology, and 15 of these patients apparently were cured.

Large doses of Alloxan failed to change the course of the hypoglycemic state in one patient.

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DISCUSSION.—DR. ALLEN O. WHIPPLE, New York, N. Y.: Our experience with this subject is based upon some 39 patients who have been operated upon, in whom we have found tumors in 33. I wish to emphasize three or four points in connection with the subject. One is the importance of adequate exploration of the pancreas. In the hands of such able surgeons as Doctor David, the finding of tumors of the pancreas will be successful in a very high percentage of cases. On the other hand, I cannot help but emphasize the importance of mobilizing the duodenum in order to expose the head of the pancreas on both sides. We have reoperated upon six patients with the finding of tumor in the head of the pancreas. The sense of feeling a mass in the tip of the pancreas after mobilizing the duodenum is so positive that one can almost be satisfied that the finding of the tumor under these conditions will be positive.

We have resected some nine cases, largely in our early cases, with not too good results, probably for two reasons; we probably overlooked the tumor, for one; and secondly, we did not resect enough of the pancreas in cases where the tumor was not present. In three cases that were resected I have reoperated and found a tumor in the head of the pancreas. These patients have been relieved of symptoms.

The second point I want to bring out is to call your attention to the very interesting and unexpected result in total pancreatectomy. I am sure it has given hours of concern and anxiety to physiologists. They cannot understand it. But a sufficient number of cases has been done to show that total pancreatectomy is compatible with life. Patients do not require as much insulin as you would expect. One requires only 40 units. They do not necessarily have altered or abnormal stools and the results are astoundingly better than one would expect. We have performed two total resections; one patient is living more than a year after operation and has done well. The second

case did not survive the operation but died on the third day; the cause of death could not be determined at autopsy.

The third point is the failure of alloxan. We have had no success with it, and I am interested in Doctor David's report. It does result in amelioration, in dogs, but it causes kidney damage, and in the absence of results in clinical cases I am afraid that method of treatment will be of no avail.

I wish to congratulate Doctor David for following-up on his first paper and collecting the data as he has.

## INDICATIONS FOR AND VALUE OF CHOLEDOCHODUODENOSTOMY\*

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AT BEST, side-tracking operations for obstruction of the bile ducts are fraught with many difficulties and dangers. The abdomen is frequently filled with adhesions, hemorrhage may be troublesome, and identification of the ducts and vessels is often a time-consuming process. Added to this, patients with a long history of duct obstruction usually present a deep jaundice with an alteration in the blood clotting time, loss of weight and strength, and advanced renal and hepatic changes. Under these circumstances, the operation should be selected with a view to its simplicity and the earliest possible restoration of normal biliary drainage.

We have been impressed with the results of choledochoduodenostomy, when feasible, as a means of relieving obstructions of the common duct. The procedure is not only comparatively simple from the standpoint of technic, but is physiologic in principle and, thus, offers a wide margin of safety. All the bile is immediately made available in that portion of the intestinal tract where it normally empties, intestinal function is soon restored, and the patient's convalescence is thereby facilitated.

Another important advantage of choledochoduodenostomy lies in the fact that the intraluminal pressure between the biliary tree and the intestinal tract appears to be equalized following operation. Ravdin and Frazier<sup>3</sup> have pointed out the danger of the rapid release of obstruction of the ducts, not merely from the loss of bile, but rather from the abrupt increase in intrahepatic pressure. They have observed that intraductal pressure incident to obstruction leads not only to pathologic changes in the liver, but to venous stasis. The rapid release of the obstruction, with the sudden flow of blood into the impaired hepatic vessels may give rise to intense hyperemia, with further circulatory disturbance and additional damage to the liver. The situation is analogous to the renal and circulatory collapse which at times has occurred following sudden decompression of the bladder and urinary tract. This effect, manifested by serious toxic symptoms, has been observed in deeply jaundiced patients following choledochotomy and drainage to the surface. With the use of choledochoduodenostomy, decompression of the ducts takes place more slowly; thus, the ductal pressure is equalized by that in the intestinal tract and this complication is avoided.

Fortunately, choledochoduodenostomy is applicable to most benign lesions and to many malignancies of the ducts and pancreas. The first criterion for the operation is that the duct must be sufficiently large to permit an adequate stoma.

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Second, the duct must be of ample length above the obstruction to permit anastomosis without tension, or, one must be able to mobilize the duodenum to a sufficient extent. If the duct is not enlarged and the condition of the gallbladder and cystic duct permits, cholecystojejunostomy is preferable. The latter procedure is usually more applicable to malignancies of the head of the pancreas wherein the gallbladder is not diseased, the common duct is not appreciably enlarged, and the cystic duct is patent. When the gallbladder has been removed, or when it is not suitable, choledochoduodenostomy is obviously one's only recourse.

We feel that the use of the gallbladder for anastomosis in the presence of infection is contraindicated. The gallbladder is a poor conductor of bile, and the infectious process induced by chronic bile stasis cannot be counted upon to become quiescent and remain so; if the infection and inflammation persist, the walls become thickened, closing the stoma and leading to a recurrence of the biliary obstruction. For the same reason, one cannot depend upon the continued patency of the cystic duct in such cases. By eliminating the gallbladder, draining the common duct, then uniting it to the duodenum, one has every assurance of the free passage of the bile into the intestinal tract and the permanent relief of the patient's symptoms.

Within recent years, we have become convinced of the superiority of choledochoduodenostomy in the presence of an enlarged duct containing multiple stones, sand and muddy material, when the distal end of the duct is small and almost strictured. In such cases, it is difficult to dilate the distal end sufficiently to insure *continuous* and *ample* drainage. Moreover, the dilated area tends to contract again and bring about another impediment to the outflow of bile. This leads to the reformation of the stones and sandy material, the original clinical picture is reproduced, and a second operation becomes necessary. Such a condition frequently develops even after choledochostomy. Following choledochoduodenostomy, on the other hand, there is little likelihood of the reaccumulation of sand and stones. The distended duct lends itself well to the creation of an anastomosis sufficiently wide practically to insure continued and adequate drainage.

Two of our cases have strikingly demonstrated to us the desirability of this type of operation as a primary procedure when the common duct is distended, partially or wholly strictured, and difficult to dilate fully. One of these cases was that of a patient who was operated upon five years ago for cholecystitis with stones and perforation. The common duct was almost as large as the duodenum and was filled with stones and thick, sandy bile. The hepatic duct, also, contained a number of stones. The gallbladder was removed, the ducts evacuated and cleansed, and the distal end of the common duct dilated with a No. 8 Sanders-Bakès dilator. A T-tube was inserted and left in place for 17 days. The patient remained well for four years. Thereafter, he began having attacks of mild epigastric pain and discomfort, chills and fever, and faint jaundice. The attacks became more frequent and more severe, until it was necessary to submit him to exploration. On opening the abdomen, the common duct was

again found to be greatly enlarged and filled with stones and sand. These were removed and the duct was anastomosed to the duodenum. Six months have elapsed since the operation and thus far the patient has been entirely free of his former symptoms.

The second patient was a woman, age 61, who had chronic cholecystitis with obstructive jaundice. The gallbladder was quite diseased, but contained no stones. Small bile cysts and biliary abscesses were scattered throughout the



FIG. 1.—The greatly enlarged common duct has been opened, the stones, sand and muddy material removed, and a futile effort made to dilate the distal end. A row of interrupted sutures of fine silk have been placed in the serosa posteriorly. The dotted line shows the site of the incision in the duodenum. The traction sutures have been left at each end to afford better exposure of the suture line. The gallbladder is shown, though it should be removed before the common duct is opened, as a precaution against the passage of stones from the gallbladder into the duct.

liver. The common duct was five or six times normal size but no stones could be palpated. After removal of the gallbladder, the common duct was aspirated and then opened, and a large quantity of muddy bile filled with sand and numerous small stones was removed. The hepatic duct was thoroughly explored, though no stones were found. The distal end of the common duct was dilated and a T-tube left in the duct. Bile drained through the tube for two weeks and, following its removal, continued to drain through the incision. The stools had practically no color, showing that most of the bile was coming to the



surface. The patient also became slightly jaundiced. Apparently, the distal end of the duct was again obstructed. The fistula persisted, and five months after the first operation the abdomen was reopened and the fistula followed down to the common duct. The duct was still quite distended, and when opened, a large amount of thick, sandy material escaped, with many small stones from the hepatic duct. After a thorough cleansing of the ducts, an attempt was made to pass dilators through the papilla of Vater, but without success on account of a severe pancreatitis. The duodenum was then freed and widely anastomosed to

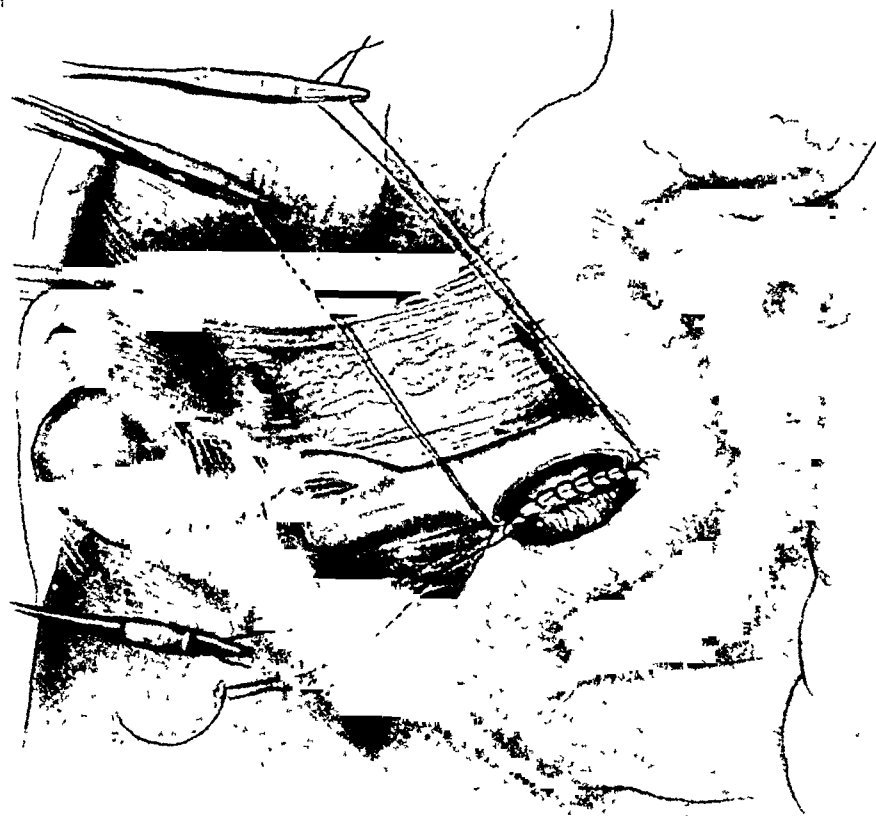


FIG. 2.—The duodenum has been opened and the mucosal layers of the duct and duodenum have been united posteriorly by a row of catgut sutures. The anastomosis is made as close to the duodenum as possible, in order to prevent angulation of the duodenum at the part nearest the liver.

the duct above the sinus. The anastomosis functioned perfectly, all the bile passing into the intestinal tract, and the jaundice cleared within a few days. The patient had no further disturbance referable to the biliary tract to the time of her death from another cause, three years later.

Incidentally, from the excellent symptomatic result in this case, it is apparent that there was no ascending infection into the biliary tree because of its connection with the intestinal tract.

A few of our experiences have demonstrated that choledochoduodenostomy is not only an advantageous operation but at times may be the means of saving a patient's life. A case in point was that of one of our most recent patients with

duct obstruction, a man, age 62, who had had a cholecystostomy nine years before for a gangrenous gallbladder containing stones. He had since had recurrent attacks of epigastric pain with jaundice. Six weeks previously, he had had another attack of pain, with chills and fever, and his stools had become putty-colored. At examination, he was extremely jaundiced, and a draining sinus led to the surface from the former cholecystostomy. On exploration, the gallbladder and cystic duct were distended and the common duct was almost as large as the duodenum. When the duct was opened, a quantity of purulent

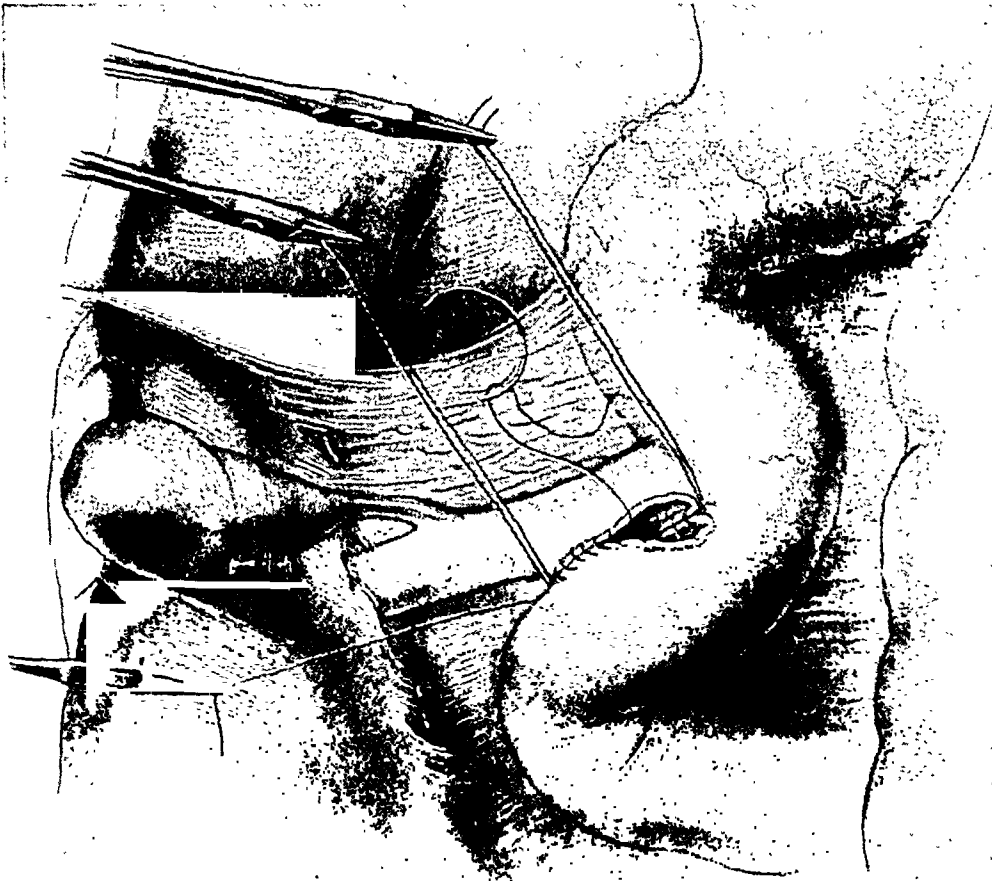


FIG. 3.—The anterior row of sutures is being placed to unite the mucosa of the duct and duodenum. This should be done without tension, though if the duodenum is properly mobilized in the beginning of the operation, there should be practically no tension.

material escaped and continued to pour out for a considerable time after the duct was emptied. This was not the typical white bile often seen in such cases, but was definitely a purulent fluid. Apparently, the liver had lost its power to secrete bile. The liver was not enlarged, but was bluish in color, incident to back pressure over a long period of time. There were no stones in the duct, but a firm mass as large as a lemon was palpated in the head of the pancreas; we could not determine whether this mass was due to pancreatitis or to a stone which had lodged there many years before. Fearing hemorrhage, the mass was not opened. After removal of the gallbladder, the common duct was thoroughly cleansed and anastomosed to the side of the duodenum. The patient made an

excellent recovery. Bile drained into the intestinal tract, the jaundice cleared and the wound healed primarily. It is more than likely that the outcome would have been fatal without this type of operation, which overcame the obstruction, allowed ample drainage of the purulent material, relieved intraductal tension, and permitted early restoration of liver function.

Except in injuries of the duct, or when a portion has been removed, it is our custom to make a lateral anastomosis, incising the duct as well as the

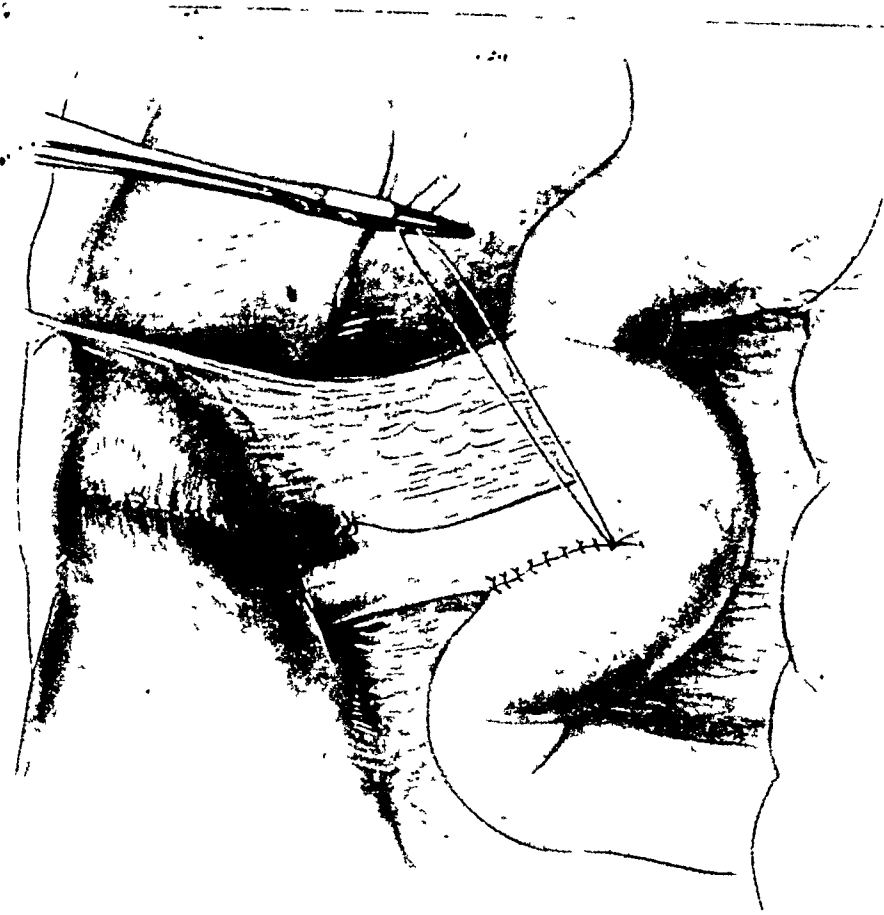


FIG. 4.—The anastomosis is completed; as a rule, the opening will admit the tip of the little finger. The anterior and posterior mucosal sutures are made with No. 000 catgut, while the interrupted serosal sutures are of fine silk. The cystic duct has been ligated and divided, the gallbladder removed and the liver notch sutured. Penrose drains are used following all these operations, but are not placed near the anastomosis line and are removed after 72 hours.

duodenum in the longitudinal direction. In the presence of injury or obstruction of the hepatic duct, if the remaining length above will not permit a lateral anastomosis, one will, of course, have to unite the end of the duct to the duodenum. In order to prevent leakage and to insure passage of the bile into the intestinal tract, we have placed several sutures in the duodenum and anchored it to the liver surface around the anastomosis. We performed this operation not long ago for a patient who had a fistula of the hepatic duct near

the liver surface, following cholecystectomy elsewhere. Below the fistula, the common duct was quite small and ended blindly, a large segment of it having been obliterated. The remaining duct was trimmed away, the duodenum was freed and the anastomosis consummated in the manner described. The patient's convalescence proceeded satisfactorily and, to the present time, she has had no further disturbance.

It has been observed that in cases of the foregoing type, wherein the duct is anastomosed near the liver hilus, the result is likely to be disappointing. Walters and Lewis<sup>4</sup> reported 98 cases of duct stricture, in 34 of which choledochoduodenostomy was performed with good results in 28 cases, whereas hepaticoduodenostomy was performed in 31, with good results in only 13. Presumably, the poorer results following the higher anastomoses are attributable largely to cholangitis incident to ascending infection from the intestinal tract. This complication has been a matter of wide concern, the ultimate effect being the formation of liver abscesses and complete hepatic dysfunction, and numerous procedures have been devised to obviate such a contingency when the common duct has been destroyed. Among the more recent of these procedures is that suggested by Allen,<sup>1</sup> which directs the intestinal current away from the liver. By this method, the jejunum is divided, the distal end sutured over a catheter to the end of the hepatic duct in the liver sulcus and anchored to the surrounding liver surface. The proximal segment of the jejunum is united to the distal end at a lower level, after the method of Roux. The tube is brought out through an opening in the jejunum and a stab wound in the abdominal wall. A vent is made in the portion of the catheter which lies within the jejunum, to permit the passage of bile into the intestinal tract; thus, there is no likelihood of an external fistula while the catheter remains in place.

Cole,<sup>2</sup> and his associates, have presented a similar operation, with the same object in view. They employ a vitallium tube instead of a catheter and, as a further precaution against ascending infection, suggest the creation of valves in the arm of the jejunum which is attached to the duct. In their experience, this procedure has been more successful than direct anastomosis of the intestine to the duct.

We feel sure that both these operations are well worth while, though, to the present time, the few patients for whom we have performed hepaticoduodenostomy have exhibited no evidence of an ascending infection and cholangitis.

We have performed choledochoduodenostomy in 22 cases and hepaticoduodenostomy in three, a total of 25 cases. Nineteen of the 25 were for obstruction by stones, stricture or pancreatitis, or for injury of the ducts. Two were for carcinoma of the pancreas and two for carcinoma of the ducts, while in two cases we could not be sure whether the obstructing lesion was a cancer of the pancreas or a severe pancreatitis (Table I).

Ten, or 40 per cent, of the 25 patients had had a previous operation, and four of these had a biliary fistula. In three cases, both operations were performed by us. Two of these three were the cases previously described. The third was that of a man, age 73, who had cholecystitis with stones and perfora-

tion, and chronic pancreatitis. The gallbladder was removed and, as the duct was only slightly enlarged and contained no stones, a T-tube was merely inserted for drainage. The probe would not pass into the duodenum, presumably on account of the pancreatitis. His jaundice persisted, and at the second operation five months later, a stricture of the duct within the pancreas was found. The pancreatitis had completely subsided. The patient died of a pulmonary complication two days after the choledochoduodenostomy.

This was one of the two postoperative deaths in the entire group. The other occurred 18 years ago; the patient had a choledochoduodenostomy, also for stricture of the common duct. The fatal outcome was apparently due to shock. These two cases constitute an operative mortality of eight per cent.

Seven patients have died since their dismissal from the hospital. Four of the seven had malignancies and succumbed to the effects of the disease. Three had benign lesions, but died months or year later of other causes. Of the remaining 16, 13 had a choledochoduodenostomy for benign obstruction of the common duct. All of the 13 have remained entirely well, not one having had any disturbance indicating an ascending infection or further obstruction (Table II).

TABLE I  
TYPES OF LESIONS AND MORTALITY IN 25 CASES OF  
CHOLEDOCHODUODENOSTOMY AND HEPATICODUODENOSTOMY

	Cases	Mortality
Carcinoma pancreas	2	0
Carcinoma ducts	2	0
Carcinoma pancreas or pancreatitis?	2	2
Benign obstructive lesions	19	2 (15%)
Totals	25	2 (8%)

TABLE II  
RESULTS IN 25 CASES OF CHOLEDOCHODUODENOSTOMY AND HEPATICODUODENOSTOMY

	Patients	Died Post-operatively	Died Subsequently	Living and Well
Choledochoduodenostomy	22	2 (11%)	7	13 (60%)
Hepaticoduodenostomy	3	0	1	2 (66%)
Totals	25	2 (8%)	8	15 (60%)

COMMENT.—From the study of this group of cases, two points are outstanding: First, the necessity for the use of every precaution in operations involving the gallbladder and ducts. The fact that in five, or 20 per cent, of the 25 cases the common duct had been damaged in a previous operation is impressive evidence of the need for wide exposure with definite identification of the vessels and ducts, and meticulous care in the use of clamps, the placement of ligatures, and in otherwise handling the tissues.

The point which we wish to make above all others, however, is that choledochoduodenostomy with the lateral anastomosis is decidedly the operation of choice when the duct is distended and the distal end is partially or wholly strictureed or may become so, or is obstructed by a mass. In such cases, choledochostomy, even with dilatation of the duodenal outlet of the duct, is likely to be

inadequate; bile stasis may recur and the duct again become distended, necessitating choledochoduodenostomy as a secondary operation. On the other hand, immediate anastomosis will prevent too rapid decompression of the ducts, will provide ample drainage, and will give every assurance against further obstruction of the flow of bile. In these respects, choledochoduodenostomy is not only a more conservative operation than cholecystostomy, but may frequently prove a lifesaving procedure.

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DR. ARTHUR W. ALLEN, Boston, Mass.: Doctor Sanders' very interesting paper gives me an opportunity to make a report of progress on our preliminary work on restoration of continuity between the biliary system and the intestinal tract, which I presented to this Association a year ago. At that time I had operated upon eight of these patients with these concepts. We felt it was fairly important to do this anastomosis in an isoperistaltic manner to prevent ascending infection. Perhaps that concept is wrong in that, when dealing with normal or comparatively normal structures, the opening may very well stay patent and the patient may not develop ascending infection. I am beginning to believe that many cases of recurrent chills and fever which occur are not all based on ascending infection, but are due to stricture at the point of anastomosis. Still I think this method of reconstruction is an easy and simple one and has some features that are valuable.

Since my original report I have had six additional cases and have learned a trick or two. I have the feeling that one should attempt to keep the anastomosis open for a long time, particularly in scar tissue, which is bound to exist in this locality. Perhaps Doctor Cole's method with the vitallium tube may be superior, but our experience has been so unhappy with this type of tube that I feel it should be replaced by other methods. We have also the experience of not having a rubber tube pass spontaneously. I have had to do two operations upon one patient because the tube did not stay in place long enough. It is difficult to determine how to fix the tube so it will stay. The best method we have been able to devise is by interrupted cotton sutures.

I believe the tube should be left in place for three months, so that fairly normal continuity may be established. If one could accomplish this I believe these patients will not have episodes of chills and fever. One is not likely to have this trouble when dealing with a large duct. The tube does not have to stay as long under these circumstances as in the cases with scar tissue from traumatic injuries high in the hepatic duct. It should be borne in mind that careful end-to-end suture is the method of choice where the lower segment of the duct is present and not fibrosed.

DR. FRANK H. LAHEY, Boston, Mass.: So much has been said in this discussion about strictures of the duct that I would like to say a word about vitallium tubes on the basis of our experience with them, lest you put too much faith in them, as I am sure we have. I feel very strongly that our conception of the value of vitallium tubes in strictures of the common bile duct was on a wrong basis. We thought of this in terms of how well the tissues will tolerate vitallium tubes when, as a matter of fact, the all important thing is, does a vitallium tube become blocked just as frequently or less frequently than does a rubber tube? In our experience, vitallium tubes become blocked

with inspissated bile just as often as do rubber tubes and, therefore, as a method of obtaining flow through the tube have no advantage whatever over rubber tubes and, due to their rigidity and inflexibility, have many disadvantages. Rubber tubes have the very desirable quality of being able to adjust themselves through the tortuous channels often present in strictures of the duct, through which the tube must pass and adjust itself without pressure. They have the additional advantage of not producing pressure necrosis that will and has in certain cases resulted from the use of the rigid vitallium tube.

We have just had a patient die at the end of ten years in whom a rubber tube completely replaced a section of his hepatic and common ducts at least three inches long, as a result of an operation elsewhere. During this ten-year period he has had no jaundice, and has been completely free from any obstructive symptoms. An autopsy was obtained and the tube was found to have been completely blocked by bile, demonstrating that the flow of bile, at least over a large portion of this ten-year period, had been not through the tube but about the tube. This brings the question up in my mind as to whether or not I have not been wrong in my desire to put in tubes of the largest possible caliber. I am not certain that we should not, in some of these cases, put in smaller ones with the hope that when they become blocked they will maintain patency and permit the flow of bile about the tube.

In an experience now in which we have operated upon 144 patients for strictures of the common and hepatic ducts, we have arrived at certain quite definite convictions. One is, and I feel very positive about this, that if there is a complete loss of substance of the duct and a tubing of any character is put in to replace this, it can never be removed without the later occurrence of a stricture. We have seen this occur now a sufficient number of times so that I feel convinced of the soundness of this observation.

We have learned, in this large experience, that there are few cases of stricture of the bile ducts in which, with good mobilization of the duodenum and division of that portion of the pancreas through which the lower end of the common duct runs, the lower end of the common duct cannot be found and, with its mobilization and the mobilization of the duodenum, its end brought up very close to the injured or severed end of the hepatic duct for anastomosis, provided that injury is not within the hilum of the liver, where it often is.

Having established the conviction that in the presence of a definite scar stricture of the duct, a permanently indwelling tube must be inserted, and having determined that vitallium tubes have no advantage over rubber, we have in two cases made use of the molded bouncing clay devised by the General Electric Company of Schenectady as a substitute for rubber. It can be molded into any shape and caliber, with a ridge about its center to prevent its being passed; it probably has no advantage whatever over rubber or vitallium tubes in its likelihood of being blocked by inspissated bile, but it does have the very great advantage that it can be molded into any shape desired and is elastic and flexible.

I wish to speak of one more lesion with which we have had experience that relates itself to this discussion, and that is the recurring common duct stone dependent upon bile stasis, and dilatation of the common and hepatic ducts due to an inadequate outlet at the sphincter of Oddi, which in these cases has become fibrosed.

We have now operated upon several of these patients in whom the recurrence of common duct stone has brought them into our hands. We have succeeded in managing these cases so that there has been no recurrence of the common duct stone by opening the duodenum, splitting the fibrosed sphincter, doing a plastic operation on the sphincter, introducing a T-tube, with one end long, into the common duct so that its lower end projects into the duodenum through the reconstructed sphincter, leaving it in for a year to 14 months until the new opening has become healed and molded. This results in adequate drainage of the distended duct, overcomes bile stasis and precipitation of its crystalline elements, as occurs when the sphincter is constricted and fibrosed, and the prevention of the recurrence of common duct stone. I have only one warning to make in connection with this operation and that is, as you introduce the T-tube into the common duct, to suture it tightly before the duodenum is opened, and demonstrate by a probe the point of entrance of the common duct and sphincter before the incision in the duodenum is made. If this is not done, one will often be surprised at what a low point in the duodenum the common duct enters as water is injected into the T-tube and squirts out at the sphincter to locate the point of entrance of the duct.

DR. ALBERT O. SINGLETON, Galveston, Texas: I am glad to have had the opportunity to hear the experiences of those who have had a large experience in the reconstruction of common bile ducts. When one has had the problem of trying to repair an injured duct it makes him extremely careful never to be responsible for this injury himself. So far as I am able to tell, the results generally of any method of reconstruction are not too flattering. Stricturing is the greatest obstacle to success. Some of our patients have gone several years without developing a stricture but eventually jaundice has occurred with toxic symptoms indicating an obstruction. Whether the infection is due entirely to the retrograde spread or whether it is due to the stricturing I am unable to say. I am inclined to believe that without stricturing infection is not a great obstacle to a permanent good result. Our experience with vitallium tubes has been disappointing. As long as the tubes have been in place (and we have used six of them) the patients have done very well, but invariably within a year or two the symptoms recur and roentgenograms have shown that the tube has passed into the intestine. We should not overlook an opportunity to spread a campaign against the untrained attempting to do gallbladder surgery and, furthermore, no one should attempt to do surgery in this region without excellent exposure and meticulous care to avoid accidents to the duct.

DR. WARREN COLE, Chicago, Ill.: I have always known that Doctor Sanders was a brilliant surgeon and a fine orator, but I did not know he was also lucky. He has had a series in which the common duct was unusually large and could be mobilized well; moreover, he has had very few cases of cholangitis of the suppurative type. However, most of this good fortune is, no doubt, well deserved because of good judgment and skillful technic. We have had a relatively large number of patients with suppurative cholangitis; three or four of these had a carcinoma of the pancreas, a lesion in which suppurative cholangitis is not supposed to develop.

The actual cause of suppurative cholangitis is not known, but I agree with Doctor Allen that stricture is a very important factor. I believe also that regurgitation of food has a lot to do with its development when the sphincter of Oddi is not present. We proved this to our own satisfaction by trying certain types of operations. Doctor Sanders showed slides of the two types we have used. When we anastomosed the hilar duct at the liver to a loop of jejunum we got regurgitation of food, and cholangitis in almost every case. In three of these patients we simply interrupted the proximal arm of the loop and made folds or valves in the distal loop. This procedure promptly stopped the chills and fever.

Doctor Sanders' method of not completely severing the duct preserves the sphincter of Oddi so that it can function in case the terminal end of the duct should open up later. If you have obstruction due to inflammatory pancreatitis, this type of operation is particularly adaptable, since the obstruction will usually disappear later with subsidence of the inflammation. I am convinced that this procedure is better than anastomosing the gallbladder to the jejunum or duodenum. I have had poor results with cholecystenterostomy because of stenosis of the stoma; I believe the only reason we do not see more failures is because the operation is usually performed for inoperable carcinoma of the pancreas, and the patients die before we have a chance to see whether or not the stoma will remain open longer than a few months. I have had two cases in which the cholecystenterostomy stoma became stenosed on three occasions. These three operations were performed by three different members of the Chicago Surgical Society and were supposedly done well.

In summarizing my ideas on the anastomosis of the hilar duct to the jejunum (when no remnant of the common duct is found), I am convinced we should anastomose the hilar duct to an arm of jejunum after the Roux principle as popularized by Doctor Whipple. We have not had any instances of obstruction of the vitallium tube, although we admit we may have been lucky. I am not yet convinced that vitallium tubes must stay in position permanently, but I do believe that they should be kept in place for several weeks, at least until the fibrosing process stops; then, if the tube drops out, we have a good prospect of having an opening which is large enough to maintain function without stenosing.

DR. R. L. SANDERS, Memphis, Tenn. (closing): I wish to thank Doctors Allen, Cole and Lahey for their generous discussion of my paper.



It is interesting to know of Doctor Allen's additional experience with the ingenious operation which he described before this Association last year. His success in 14 cases certainly justifies further trial of the method when reconstruction of the injured duct is indicated.

Doctor Cole referred to my good luck in the cases reported. I am not sure that the results have been due to good luck. In the presence of an abnormally large common duct, a side-to-side anastomosis to the duodenum is a more physiologic operation than an end-to-side anastomosis. By making the stoma sufficiently wide, one may expect it to remain patent, and the bile to pass freely and continuously into the intestinal tract. Because of the equalization of pressure between the biliary and intestinal tracts, ascending infection should not be a serious consideration. Thus far, none of our patients have exhibited any clinical evidence of ascending infection.

In regard to Doctor Lahey's discussion, I am not at all in accord with his idea of making an easy operation difficult. Moreover, to do any plastic operation on the lower end of the common duct, particularly with the use of the transduodenal approach, is to invite trouble. This is especially true of those cases wherein an extensive pancreatitis, with edema and induration of the tissues, is associated. The operation I have described is really a short-circuiting procedure, similar in principle to gastro-enterostomy for obstruction of the pylorus, the distal portion of the duct being undisturbed as it passes through the pancreas. The technic is simple and readily executed, and the danger of opening inflamed areas is obviated. Also, the likelihood of further obstruction from the reformation of stones is negligible. If Doctor Lahey will try this method, making a simple lateral anastomosis with a very large stoma, I am sure he will appreciate its merits.

# MALIGNANT TUMORS OF THE SMALL BOWEL\*

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CARCINOMA OF THE SMALL BOWEL is quite rare. Dougal states that not over 300 cases have been reported. One may be sure, however, that a large number of sporadic cases—and most surgeons will only have isolated experiences with this condition—have remained unpublished. This is regrettable because the diagnostic and therapeutic management of carcinoma of the small bowel must be considered utterly unsatisfactory and only by applying cumulative knowledge may one expect an improvement in this situation. It is for this reason that we feel justified in reporting two cases of carcinoma of the small bowel, one of them typical, the other, peculiarly interesting because of the occurrence within 2.5 years of two separated malignant lesions of the intestinal tract.

## CASE REPORTS

**Case 1.**—Mrs. E. R., white, age 33, was admitted to the Chesapeake and Ohio Hospital, May 23, 1945, with the following history: Her mother had died of cancer of the stomach. Her past history was not contributory. She had had no children, but had had one miscarriage. An appendectomy had been performed in 1932 for acute appendicitis. Her present complaints dated back about six months. During that time she had experienced gradually increasing gaseous distress, gurgling and rumbling in the area of the stomach and upper abdomen. During the three weeks before admission she had nausea and vomiting after the noon and evening meal, but not after breakfast. She noticed considerable distention in her epigastric region immediately following meals. The vomitus was described as being bitter and containing particles of food. It usually occurred one or two hours after eating, and she felt very relieved of her distress after she had vomited. She had lost about eight pounds of weight. Physical examination was negative. Gastric analysis showed normal values. Hemoglobin was 84 per cent. The red count was 4,360,000. The white count was 5,850. A diagnosis of partial intestinal obstruction was made. Gastro-intestinal roentgenologic series showed a normal esophagus and stomach except for marked pylorospasm. The entire duodenum was dilated, but no defects were noted. After two hours there was considerable gastric retention and the duodenum was still distended. The same findings persisted for a five-hour period. The dilated duodenal section ended abruptly at the duodenojejunal junction.

*Operative Procedure.*—May 26, 1945: The abdomen was opened through a high, left, paramedian incision. An annular constricting lesion was found at the duodenojejunal junction. A circular ulcerated carcinoma was present at this site. The entire thickness of the wall was made up by tumor. Many small mesenteric nodes were found in the jejunal mesentery. The complete segment of involved jejunum, with a cuff of normal bowel four inches way from the lesion on either side, along with the mesentery, was resected and an end-to-end anastomosis was established. The wound was closed anatomically.

*Microscopically,* the tumor was a highly differentiated papillary adenocarcinoma destroying the intestinal wall and metastasizing to the majority of the dissected lymph nodes was present. There was also Lymphadenitis, obviously secondary to the ulceration of the mucosa.

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\* Read before the Fifty-seventh Annual Session of the Southern Surgical Association, December 4-6, 1945, Hot Springs, Virginia.

The patient made an uneventful recovery, and was discharged from the hospital on June 8, 1945. This patient was seen within the past ten days and is apparently in excellent condition, without symptoms. However, it is realized that optimism as to a permanent cure is not warranted.\*

**Case 2.**—W. V., a 66-year-old white male, had been suffering with intermittent constipation and diarrhea and various digestive disturbances for two years. When first seen, in May, 1942, he had been sick for two weeks with pain around the umbilicus, nausea



FIG. 1.—Case 1: Roentgenogram showing obstruction at duodenojejunal junction and dilatation of duodenum.

and vomiting. His bowels were moving three or four times a day, but only a very small amount of stool which contained blood was passed each time. He stated that similar episodes had occurred almost every year during the past 15 years. Two years prior to the time that he was seen, his habitual constipation gave way to moderate diarrhea, which lasted for about a year. Later his constipation recurred. He had lost appreciable weight.

Physical examination was essentially negative, except for a moderate intestinal distention and tympanism of his abdomen. No masses were felt. A presumptive diagnosis of low intestinal obstruction, due probably to a tumor, was made. Roentgenologic studies of his lower intestinal tract, with the use of barium enemas, proved very difficult and unsatisfactory because of a very marked atonia of the bowel. The roentgenologist felt that he could not arrive at a positive conclusion, but he thought that here was a partially obstructing lesion at the midportion of the sigmoid. Proctoscopic examinations were negative for tumor. Laboratory studies were not helpful. Red and white blood counts were normal.

\* On Jan. 8, 1946, the patient was operated on for a massive pelvic tumor. Both ovaries were tremendously enlarged. Metastatic adenocarcinoma with marked proliferation of stroma was found.

FIG. 4

FIG. 5

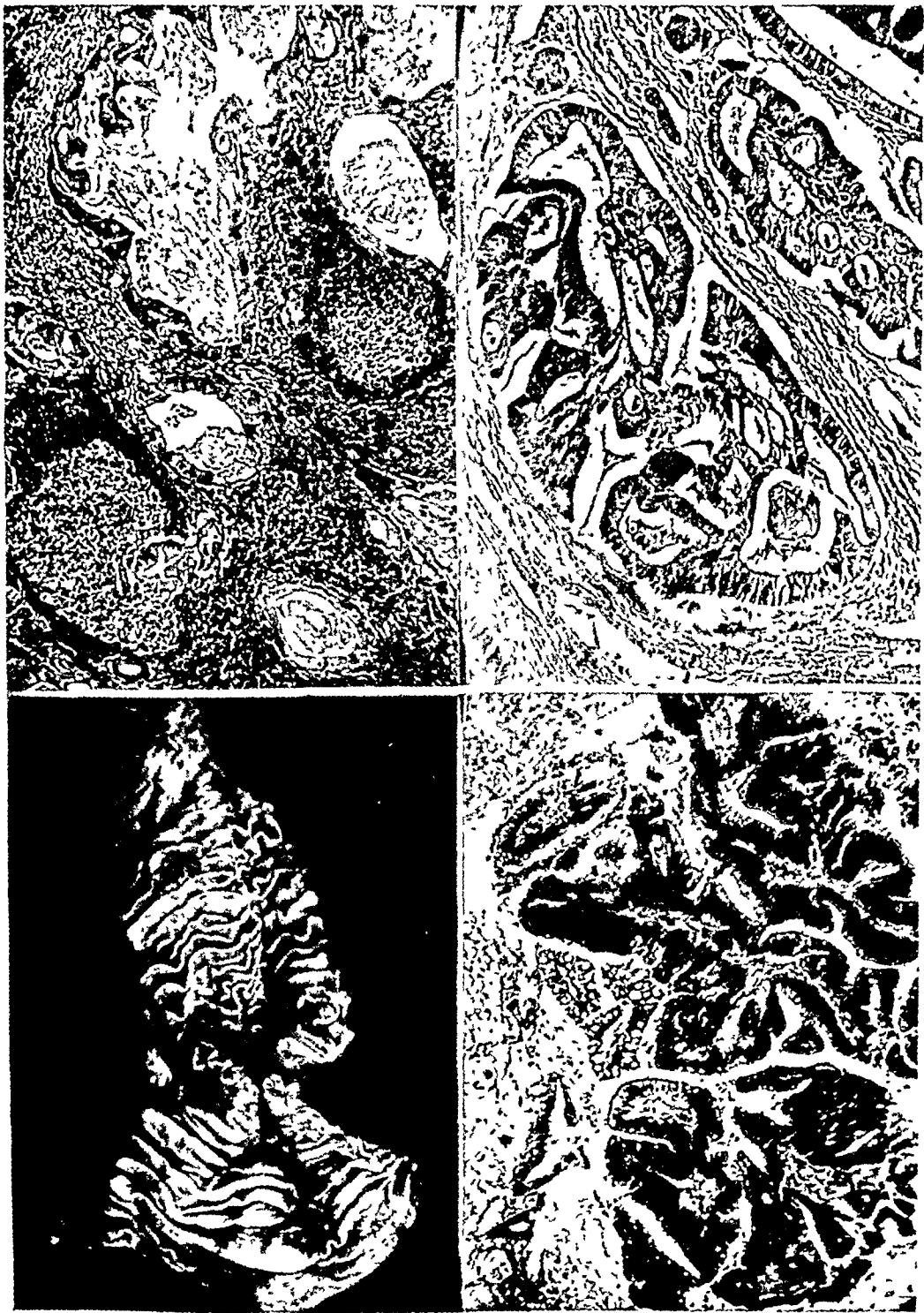


FIG. 2.—Case 1: Operative specimen with stenosing circular carcinoma.  
FIG. 3.—Case 1: Microscopic appearance of tumor in intestinal wall.  
FIG. 4.—Case 1: Metastatic tumor in regional lymphnode.  
FIG. 5.—Case 2: Microscopic appearance of primary tumor of sigmoid.

FIG. 2

FIG. 3

*Operative Procedure.*—June 6, 1942: The abdomen was explored and a constricting neoplastic lesion of the upper sigmoid was found. An abdomino-perineal resection, after the method of Myles, was performed. The resected specimen was 32 cm. long, contained a cauliflower type of tumor, beginning 16 cm. above the anus and involving the sigmoid for a distance of 6 cm. The serosa was not grossly involved. The sigmoid was found to be adherent to a loop of small intestine. The tumor proved to be a typical adenocarcinoma of the large bowel which involved the muscular layer, but did not infiltrate the serosa.

The patient made a satisfactory recovery, and was discharged from the hospital 18 days later.

He was readmitted, in March, 1945, approximately three years later. He had been doing well until two months previously, when he began to vomit after meals. This vomiting became more exaggerated and his abdomen became distended. The colostomy began to need frequent irrigations and the stool specimens became liquid and scanty and contained some blood. The vomitus contained usually food just eaten. He had lost weight rapidly.

*Physical Examination.*—The patient was poorly nourished and greatly dehydrated. The abdomen was distended. No masses were felt. He had a mild anemia of 67 per cent hemoglobin, 3,950,000 red cells. The clinical diagnosis was partial intestinal obstruction, probably due to extension of the malignant lesion of the sigmoid. Gastro-intestinal roentgenologic series showed only a marked gastric stasis. After two hours the barium was still in the stomach. An 18-hour film was made after the patient had vomited a large amount of barium, and showed distended coils of small bowel. The roentgenologic diagnosis was not helpful, although the roentgenologist felt that the patient had an obstructive lesion of the small bowel.

*Operative Procedure.*—March 11, 1945: The patient was explored and an obstructing, constricting neoplasm was observed in the distal ileum just proximal to the ileocecal valve. It was relatively easy to resect the distal ileum, the cecum, and ascending colon. An ileocolostomy was established.

The patient made a very satisfactory operative recovery, and was discharged from the hospital on March 20, 1945. He died six months later at home.

*Pathologic Report:* The specimen consisted of 20 cm. of small bowel, cecum, appendix and initial portion of the ascending colon. A round, firm tumor mass, 5 cm. in diameter, was found in the ileum, only a short distance from the ileocecal junction. Corresponding to it, there was a circular, stenosing ulceration. The wall in this area was 3 cm. thick, firm, and the muscle was replaced by a mottled greyish and yellowish tissue. The serosa was slightly opaque. On microscopic examination, the mucosa and the muscularis were destroyed by an adenocarcinoma, with some tendency to formation of papillae. There was hardly any evidence of secretion on the part of the tumor epithelium. There was much necrosis and the muscularis was extensively and deeply invaded.

Comparison of the histologic features showed, beyond the different localization of the second tumor, that this patient had two primary tumors of the intestinal canal—the first one of the sigmoid, the second of the ileum.

*DISCUSSION.*—In estimating the incidence of carcinoma of the small bowel it must be kept in mind that the older statistics, based on large numbers of autopsies, include in the neoplasms of the small bowel malignant lesions other than carcinoma, such as sarcoma and carcinoid, and are, therefore, not accurate. Ewing estimates that 3 per cent of the carcinomas of the gastro-intestinal tract—from the cardia to the anus—are located in the small intestine, and this figure can be considered as representative. In comparison, 60.7 per cent of all gastro-intestinal sarcomas occur in the small bowel (Shallow). There is some discrepancy among the various authors regarding the distribu-

tion of carcinoma in the three main divisions of the small intestine, which is not surprising since most series are quite small and none reaches 100 cases. Slightly less than one-half of the carcinomas occur in the duodenum, but this figure would include tumors of the papilla of Vater. Ileum and jejunum are about equally involved by malignant neoplasms in general, but sarcoma, as well as carcinoid tumors, are considerably more frequent in the ileum and carcinoma correspondingly more rare.



FIG. 6.—Case 2: Microscopic appearance of primary tumor of jejunum.

There is no satisfactory explanation for the relative infrequency of carcinoma in the small intestine. The alkaline reaction and liquid consistency of its contents have been mentioned as being possibly responsible, as have the absence of sharp bends and abrupt transitions of one type of epithelial lining to another. However, all this must be considered sheer speculation.

As to their gross appearance, one can distinguish an infiltrative and a fungating type. The former is more apt to produce a napkin ring type of stenosis; the latter tends more to ulceration and occasionally to intussusception. However, as a rule, malignant lesions show much less tendency to intussusception than benign tumors, such as lipomas or myomas. Microscopically, they are all adenocarcinomas, with some variations in the details of their pattern.

It is remarkable how early carcinoma of the small intestine metastasizes, or rather, in how many cases metastases are present when the primary tumor is discovered. In Shallow's series, 31 of 38 cases showed metastases or extension. The metastases occur into the regional lymph nodes, the liver, pancreas, retroperitoneal lymphnodes, lungs and bones, in this order.

In about 80 per cent of all cases a quite typical history can be obtained. Cramps, epigastric distress, bloating, rumbling, and short, recurring episodes of obstruction are the principal symptoms. Occult blood and moderate anemia may be present. Shallow found a palpable mass in 75 per cent of his cases—which is truly remarkable. The average duration of symptoms is about six months. Only occasionally is the onset dramatic, with perforation, massive hemorrhage or acute obstruction.

The most important single diagnostic method is the roentgenologic examination of the small bowel. This is difficult procedure, even in the most experienced hands, as evidenced by Shallow's statement that in only one-half of his cases examined roentgenologically could the lesion be demonstrated. In this connection, it should be borne in mind the just-mentioned fact that the same author could palpate a tumor in 75 per cent of his cases.

The almost ordinary presence of metastases makes extensive surgery necessary in most cases. This, and the generally poor condition of the patients, with a long-standing malignant lesion in the absorbing portion of the intestines, accounts for the almost incredibly high operative mortality of 44 per cent. The mortality is even higher for the duodenum, but somewhat lower for the ileum. Nevertheless, resection, with anastomosis, is indicated even in the presence of metastases because of the temporary relief from an ulcerated, bleeding lesion and obstruction. Postoperative radiation has apparently not shown any remarkable results. It is being used, though, in view of the poor results obtained with surgery alone. It is estimated that not more than 5 per cent of patients with carcinoma of the small intestine survive the five-year period.

Since the technic of intestinal resection is highly perfected, the main effort of improving the deplorably poor therapeutic results must be directed toward early diagnosis and optimal preoperative preparation. While much progress has been made in the latter respect in recent years, one cannot be optimistic as to earlier diagnosis, with the present diagnostic methods. Until better means are found, we must rely on our clinical skill, based on personal and common experience. With this consideration in mind, this report has been presented.

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DISCUSSION.—DR. G. V. BRINDLEY, Temple, Texas: This is an excellent paper upon a very important subject. I should like to emphasize a few facts brought out in the paper.

It is true that the tumors of the small bowel are diagnosed late, and this is probably a most important factor contributing to the poor prognosis of these lesions. The tumors are usually not demonstrated by routine roentgenologic studies of the gastrointestinal tract, but to diagnose such neoplasms a special small bowel study is required.

In the ten-year period between 1935 and 1944 there were seen in the Scott and White Clinic 17 patients with tumors of the small bowel; 11 of these were carcinoma and six were sarcoma. A majority of these patients had rather advanced lesions when first seen, as were the cases reported by the essayist. The predominating symptoms in most instances were those of variable degrees of obstruction. However, one case with a carcinoma of the jejunum was admitted shortly after a profuse intestinal hemorrhage, necessitating several transfusions.



## RESTORATION OF CONTINUITY AFTER RESECTION OF THE RECTUM\*

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THE FIRST CONCERTED ATTEMPTS to remove cancer bearing areas of the rectum at the end of the last century were unsatisfactory, having a large mortality and morbidity and a high percentage of recurrence. In 1907, Miles deserted the Kraske type of posterior resection with anastomosis or sacral anus in favor of combined abdominoperineal resection and so popularized the latter procedure that it became the most widely employed for removal of cancer of the rectum. Lockhart-Mummery, in 1914, first performed the type of resection known by his name, which consists of preliminary colostomy and subsequent posterior resection of the rectum. These two operations have been popular during this century, and in recent years abdominoperineal resection in its original or modified form was undoubtedly the first choice of most surgeons.

During all this time, the thought of colostomy has continued to be abhorrent to patients and many doctors, though the salvage of over 40 per cent of the lives otherwise doomed by cancer of the rectum has been a recompense worth that burden. But even then, the realization that life alone is not enough has spurred thoughtful men to continue the technical search for some method of removing the cancer adequately wide to affect a high rate of cure and yet permit restoration of the normal course and control of intestinal evacuation. In the past, feeble attempts were made in this direction, but more recently arresting reports have been made by Dixon, Wangensteen and Babcock and Bacon. No one who does only abdominoperineal resection for cancer of the rectum and rectosigmoid can read these reports without at least some doubt arising as to the choice of an operation for these lesions.

The assay as to whether it may be correct to remove the cancer bearing rectum and restore continuity will depend on the results compared to abdominoperineal resection of the rectum. This will include mortality rates, five-year cures, and postoperative sphincter function. So far, only such series as those reported by Dixon, Babcock, Bacon, and Wangensteen in this country, are large enough to be helpful ultimately in determining these factors. The superior type of operation chosen for restoring function also will not be determined easily, since there are many possibilities and combinations. Dixon and Wangensteen prefer an abdominal resection and anastomosis while Babcock and Bacon use a clever modification of the Hockenegg operation, undoubtedly more radical for the lower growths. Mandl, after a study of 1,000 cases from Hockenegg's Clinic, indicated his belief that sphincter preservation does not

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\* Read before the Fifty-seventh Annual Session of the Southern Surgical Association, December 4-6, 1945, Hot Springs, Virginia.

# RESECTION OF THE RECTUM

increase the incidence of recurrence of carcinoma. He prefers the Hockenegg pull-through operation which he had performed in the last 17 of 54 radical resections. His other resections were done by the Miles procedure. However in his cases, he reported the use of pull-through operations for lesions as high as 16 and 18 centimeters up from the anal outlet. Anterior resection with

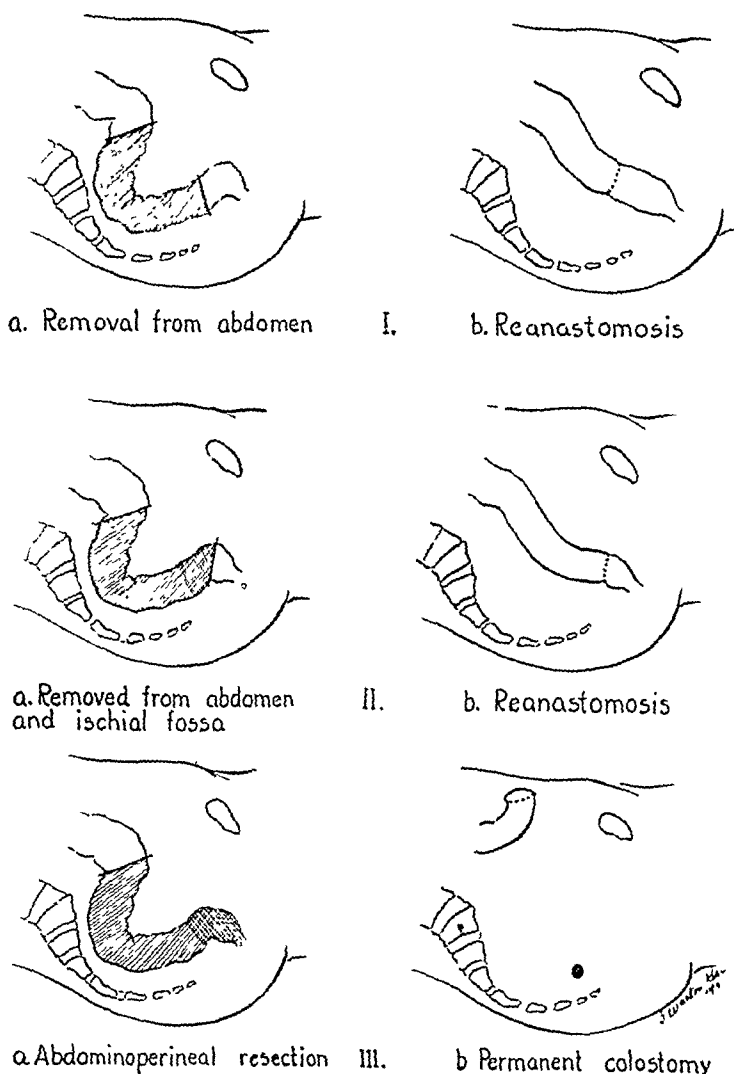


FIG. 1.—Three plans of resection for rectal carcinoma. Lesions in the rectum at least eight centimeters from the anal outlet may be removed and continuity reestablished transabdominally. Lesions extending below that level may be removed by abdominoperineal resection with abdominal colostomy or in certain cases by a combined anterior and posterior resection and anastomosis.

anastomosis would be easy in such high growths and I believe that for lesions at that level, both Hockenegg pull-through procedure and abdominoperineal resection will be replaced in popularity in the near future by the anterior resection and anastomosis.

The last 20 resections of the rectum or rectosigmoid on my private services have been done in one stage without preliminary colostomy. In 13 patients, attempts were made to reestablish normal positional continuity of the

bowel, *i.e.*, after resection of the rectum for carcinoma, an anastomosis was made by one of several means and in one instance, after complete resection of the rectum, the sigmoid was replaced through the sphincter. The effort to reestablish continuity failed in three patients though they recovered with a permanent colostomy. There were two deaths in the 20 resections. One fol-

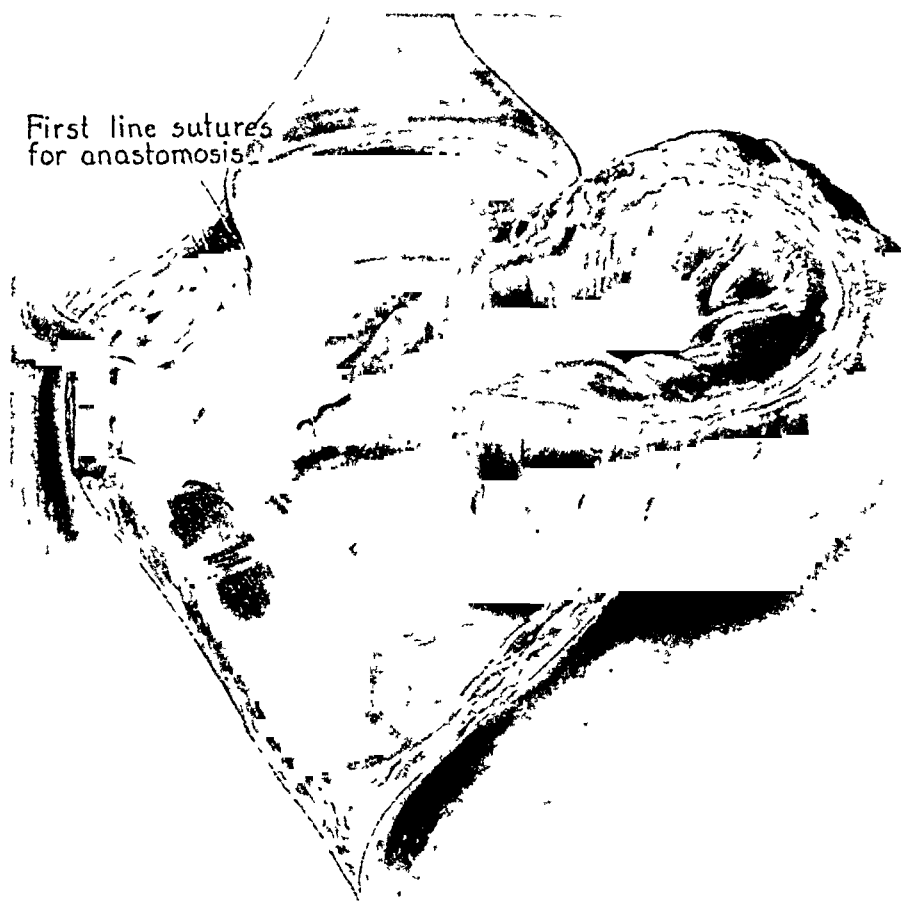


FIG. 2.—Attachment of the sigmoid to the rectum after mobilization of the rectum for removal of a growth partially below the peritoneal reflexion. Lesions at this level can be brought up surprisingly high when all attachments of the rectum are freed down to the levator ani muscles.

lowed abdominoperineal resection of the rectum in one stage and another death followed transabdominal resection and anastomosis.

Transabdominal resection of the rectum was done according to a technic, essentially that described by Dixon. After exposing the abdomen through a midline incision, the peritoneum on each side of the mesosigmoid is cut. This incision is extended down into the pelvis on either side of the rectum. The incision in the peritoneum extends anterior to the rectum in the rectovesical or recto-uterine pouch. The superior hemorrhoidal vessels are identified and are transected and ligated at the promontory of the sacrum. Then the hand separated the two severed portions of the peritoneum and posterior to the hemorrhoidal vessels separates the rectum and retrorectal tissue from the hollow of

## RESECTION OF THE RECTUM

the sacrum, down to the coccyx. The lateral and anterior attachments of the rectum are severed as far down as the growth-bearing segment may be drawn out and up amazingly high so that the growth-bearing segment then may be delivered even outside the abdominal wound. I prefer, after attaching the sigmoid to the rectum sufficiently far below the growth, to apply a Furniss

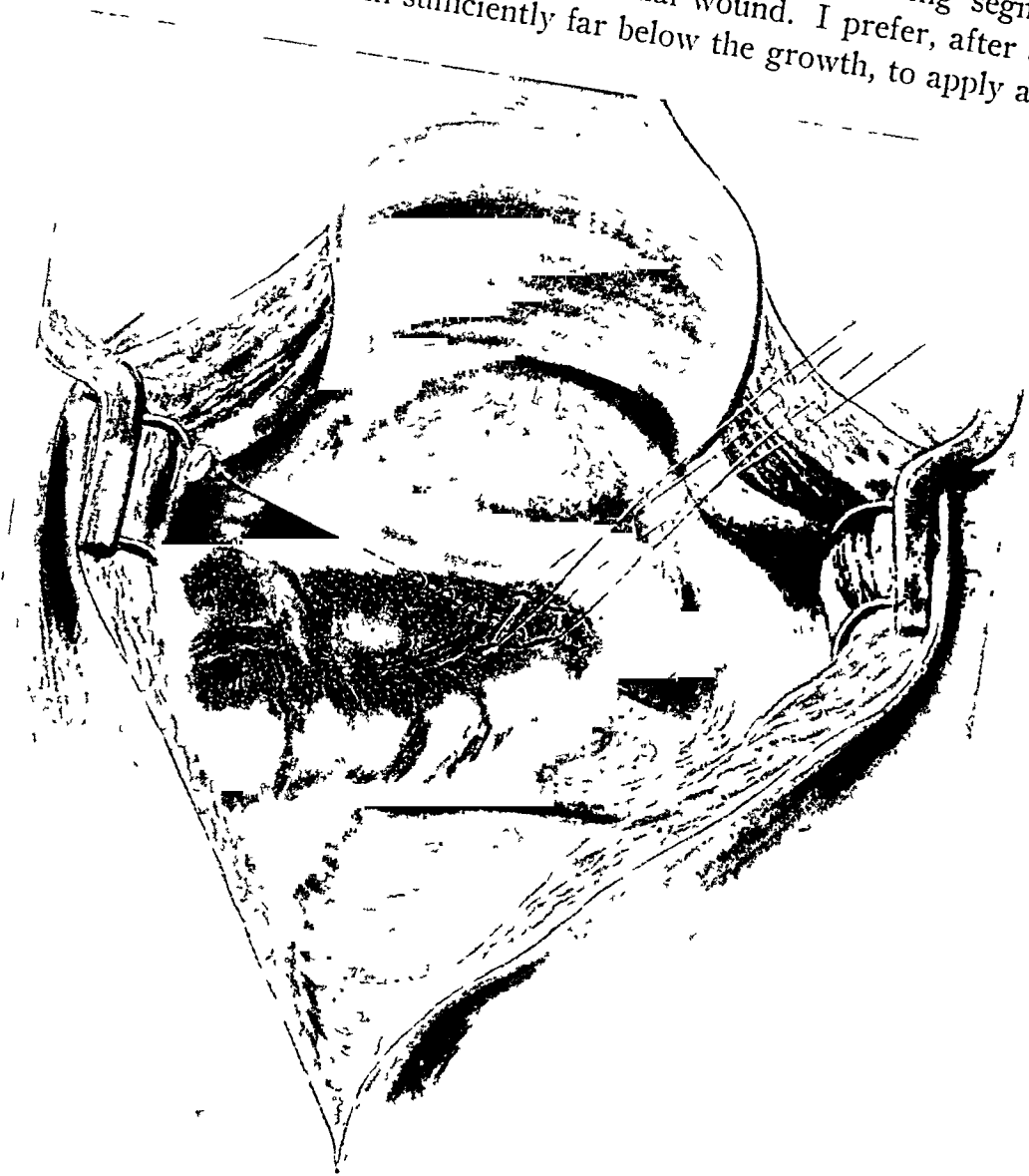


FIG. 3.—Aseptic anastomosis of the sigmoid and rectum with a Furniss clamp. If the remaining rectal segment is too short, a Parker-Kerr anastomosis may be accomplished.

clamp and remove the growth-bearing loop; or should the use of the Furniss clamp be unhandy because of a compromised space, I have chosen a Parker-Kerr technic for the anastomosis. I have not done an open anastomosis, though I realize this method has been used with a satisfactorily low mortality by Dixon, and others.

I usually do not make a complimentary colostomy but prefer a catheter

enterostomy in the sigmoid proximal to the anastomosis. The sigmoid is sutured to the parietal peritoneum near the emergence of the catheter which is brought through a stab wound in the abdominal wall. Colostomy may be an advantage however in poorly prepared or partially obstructed colons.

In this operation, with reestablishment of continuity, rectosigmoid growths and rectal growths down to the lowest part of the rectum can be removed with

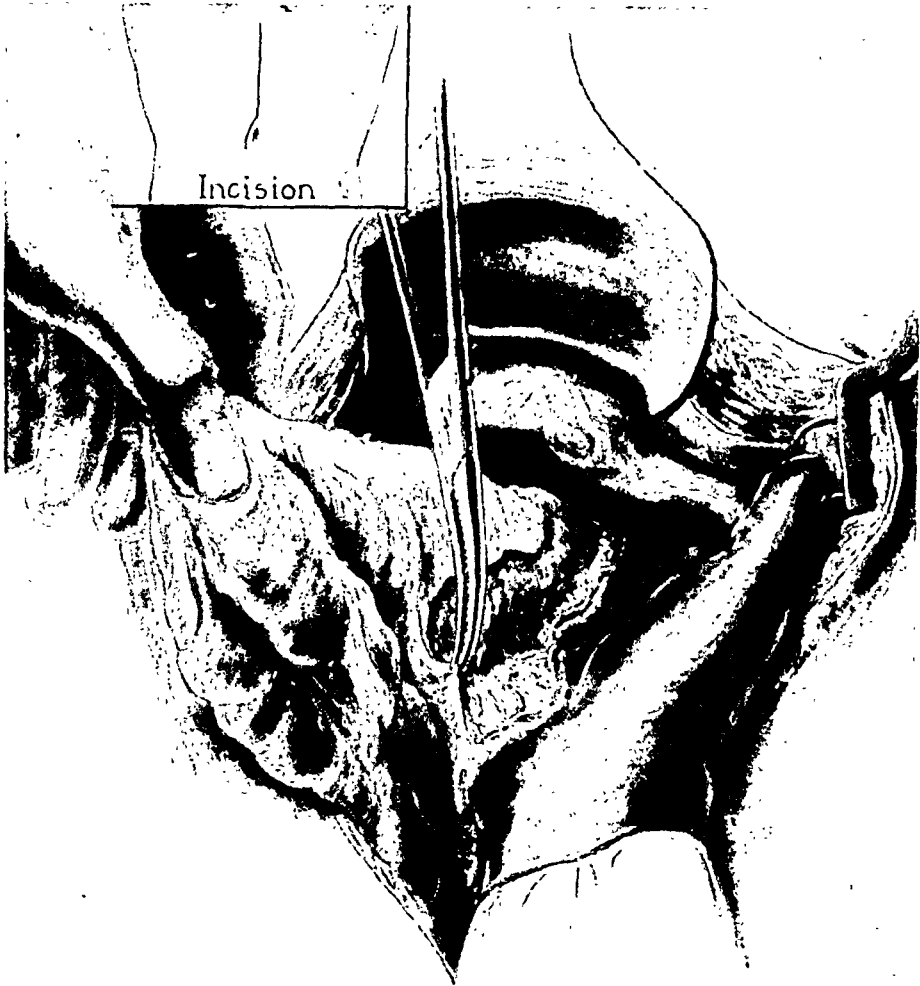


FIG. 4.—Mobilization of the rectum in an abdomino-ischial resection of the rectum for extremely low rectal growths. The rectum may be freed without first ligating the superior hemorrhoidal artery. This is done to preserve better blood supply to the upper segment.

as much ablation of perirectal tissue and nodes as is accomplished in the Miles' abdominoperineal resection. But more tissue may be removed inferiorly and for the extremely low growths laterally in the Miles' type of operation. This probably has some bearing on the results for low rectal carcinoma and it probably has none for the high ones. The careful pathologic studies of Gilchrist and David, and Coller, Kay and MacIntyre, support the clinical impression that carcinomas of the rectum metastasize upward or laterally but not downward.

I have been able to remove a carcinoma by transecting the bowel three to four centimeters below the lowest gross extension of the growth and effect an anastomosis between the rectal stump and the sigmoid transabdominally when the lower end of the growth was no more than eight centimeters above the external sphincter, (external end of the anal canal) measured at proctoscopic examination before operation.

It is surprising how high up the rectum may be brought when it is mobilized in this operation. A growth at the peritoneal reflexion may be delivered up to the abdominal wall or even higher. This is due not only to elasticity of the rectum, but also in part to the curves of the normal rectum which, when loosened and rectified into a straight angle, add considerable length to an otherwise very short segment.

For those lesions whose lowest level is below eight centimeters above the anal outlet, it still may be feasible to remove the segment containing the growth and preserve the sphincter by one of several different procedures. Gaining in popularity is the Hocke-negg procedure which has been advocated in this country only by Bab-

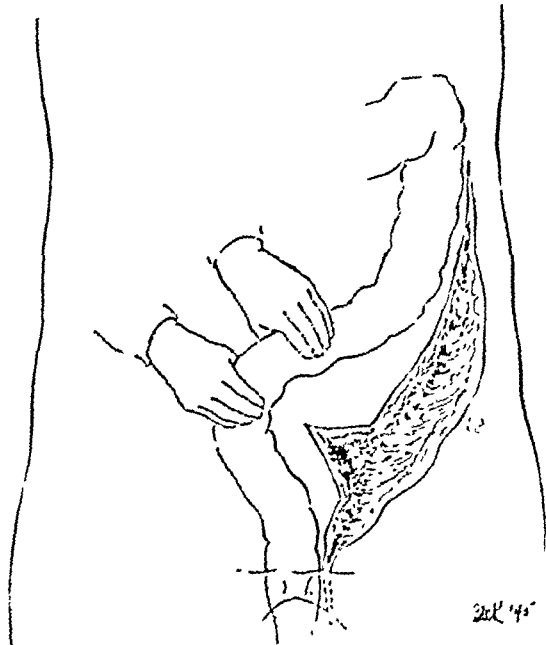


FIG. 5.—Incision into lateral peritoneal attachment to facilitate descent of the sigmoid into the pelvis for abdomino-ischial resection and anastomosis.

cock and Bacon. Babcock, long an objector to abdominal colostomy, preferring even perineal colostomy, has described several methods of dealing with the lower stump in an abdominoanal proctectomy to reestablish continuity or normal position of the bowel with or without preservation of the sphincter. He deserves great credit for so long and so insistently championing the cause for normal continuity when few in this country adhered to his teaching.

I have attempted to reestablish normal continuity in five patients in whom the growth was too low to remove and perform anastomoses transabdominally. At least, part of each carcinoma was below eight centimeters above the external outlet of the anus, but the growth was still above the internal end of the anus. In the first three, the rectum was mobilized in the abdomen after ligation of the superior hemorrhoidal artery at the promontory of the sacrum. The abdominal wound was then closed and the patient turned. The rectum was delivered through a midline wound posteriorly, and the growth-bearing segment of the bowel removed and the sigmoid anastomosed to the stump of the rectum by interrupted sutures.

The rectum in all three of these sloughed, and it was necessary in the two who did not already have a complimentary colostomy to make one. All three

patients recovered but with permanent abdominal colostomies. In two patients since then, a successful anastomosis has been made from below by the following operation. The rectum was mobilized through a midline abdominal incision as

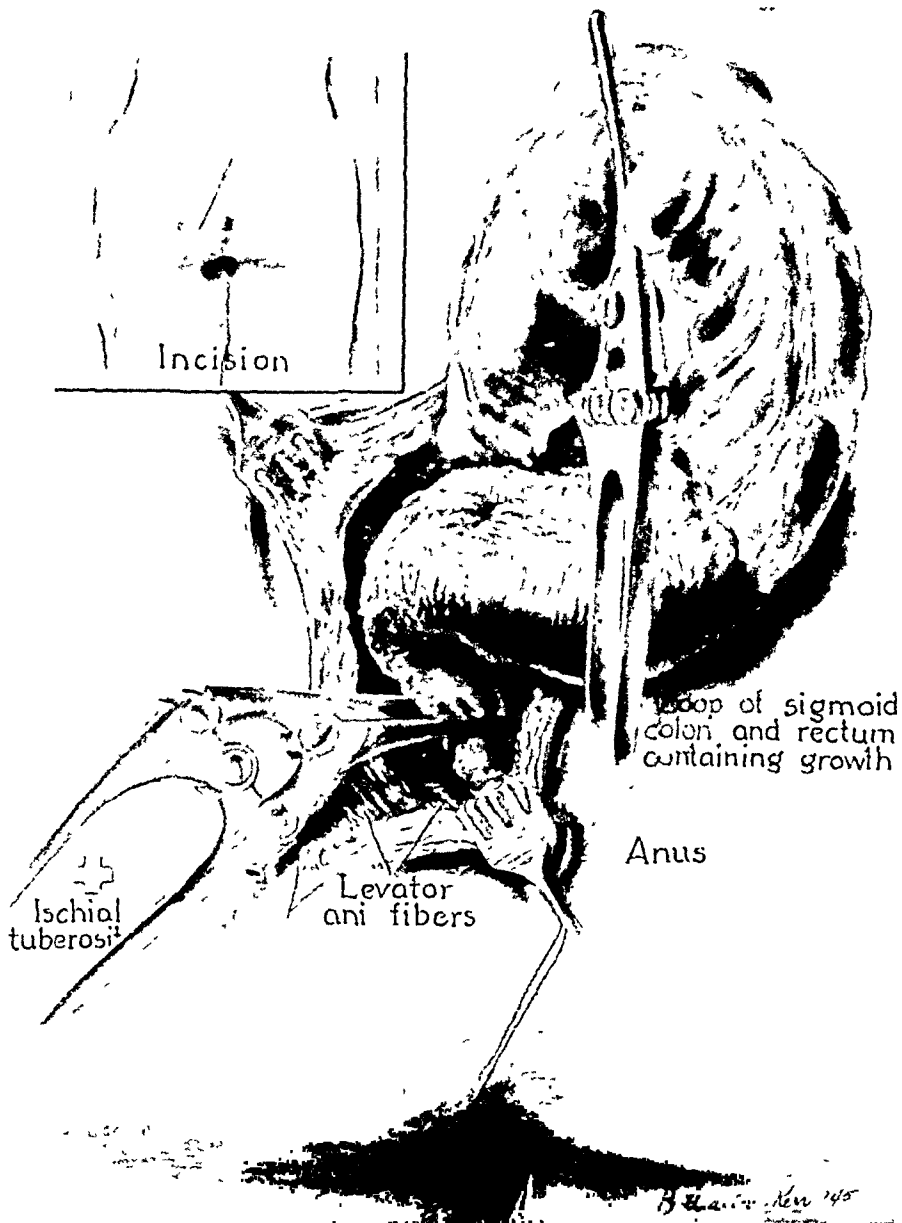


FIG. 6.—The ischial portion of an abdomino-ischial resection. An incision is made over the ischial fossa and is extended through the levator ani muscles on one side. The rectum is delivered and is removed leaving a stump only a few centimeters proximal to the anus. The superior hemorrhoidal artery is ligated high at a level which will not compromise blood supply to that area of the sigmoid which may be anastomosed without tension.

in the abdominoperineal resection. Exceptions, however, were made. The superior hemorrhoidal artery was not ligated at this stage. I found that it is perfectly feasible to mobilize the rectum from the sacrum when the superior

hemorrhoidal artery is not ligated and without too much hemorrhage if the separation from the sacrum by the hand is carefully done, entirely posterior to the hemorrhoidal vessels. In addition to this, the sigmoid and the descending colon was mobilized by cutting the lateral peritoneal folds. Then crucial cutting of peritoneum in the mesosigmoid allowed more rectification of the sigmoid loop for its descent into the pelvis. The rectum and sigmoid were then pushed into the pelvis and the peritoneum released laterally was sutured over it, and around the sigmoid to form a new high pelvic floor. After the abdominal wall was closed, the patient was turned and an oblique incision was made from the tip of the sacrum in the midline downward and outward over the ischiorectal space and ending anterior to the anus and midway between the tuberosity of the ischium and the anus. The incision was deepened, cutting through perianal fat and through the levator ani. The coccyx was disarticulated and the presacral fascia incised. This permitted delivery of the already mobilized rectum. Farther dissection freed the rectum from the levators and it was thus possible to transect this segment just above the anal canal. The sigmoid was then pulled well down to a level where it could be approximated to the remaining rectal stump without too much tension. Then only was the blood supply ligated and at that level. The anastomosis was made as an open anastomosis because the rectal stump was too short and the space too small to permit application of a clamp. Because they have been done recently, in neither of these cases has the complimentary colostomy yet been closed, though the immediate results have been encouraging enough to make me feel that further use of the method for certain low rectal growths is justified.

This plan of resection has the advantage that the abdominal portion of the resection removes the regional nodes, and the posterior part is done in a manner to result in little damage to sphincter mechanism. Its limitations are obviously the restricted removal close to the growth in the lower areas. It may be applicable for certain lesions low in the rectum, but its worth has yet to be proved when compared with the more radical Hockenegg procedure, and for lesions at that level when compared with results of abdominoperineal resection.

DISCUSSION.—What will be the limits for which anterior resection of the rectum and anastomosis may be accomplished? Apparently, any segment down to a distance of five centimeters above the anal outlet. Since the anal canal is three centimeters in length and two centimeters above that is a very short rectal segment almost all the rectum may be removed and continuity restored transabdominally. I have found that I can remove, transabdominally, any growth the lower limit of which is eight centimeters or above from the *external* anal sphincter. This allows for the removal of at least three centimeters of rectum below the lowest gross extension of the growth, or section of the rectum, five centimeters above the anal outlet. Apparently Wangenstein has found the limitations of anterior resection to be about the same when he says: "Strange as it may seem, after mobilization, anastomosis may be effected . . . as close as five centimeters from the anus."

It will be more questionable whether resection and anastomosis should be



employed for the lower rectal growths. For the higher lesions virtually the same radical removal may be effected as by abdominoperineal resections, whereas in the lower lesions, the pelvic fascia and levator ani are left in close proximity for lateral spread from the growth. Fortunately most carcinomas

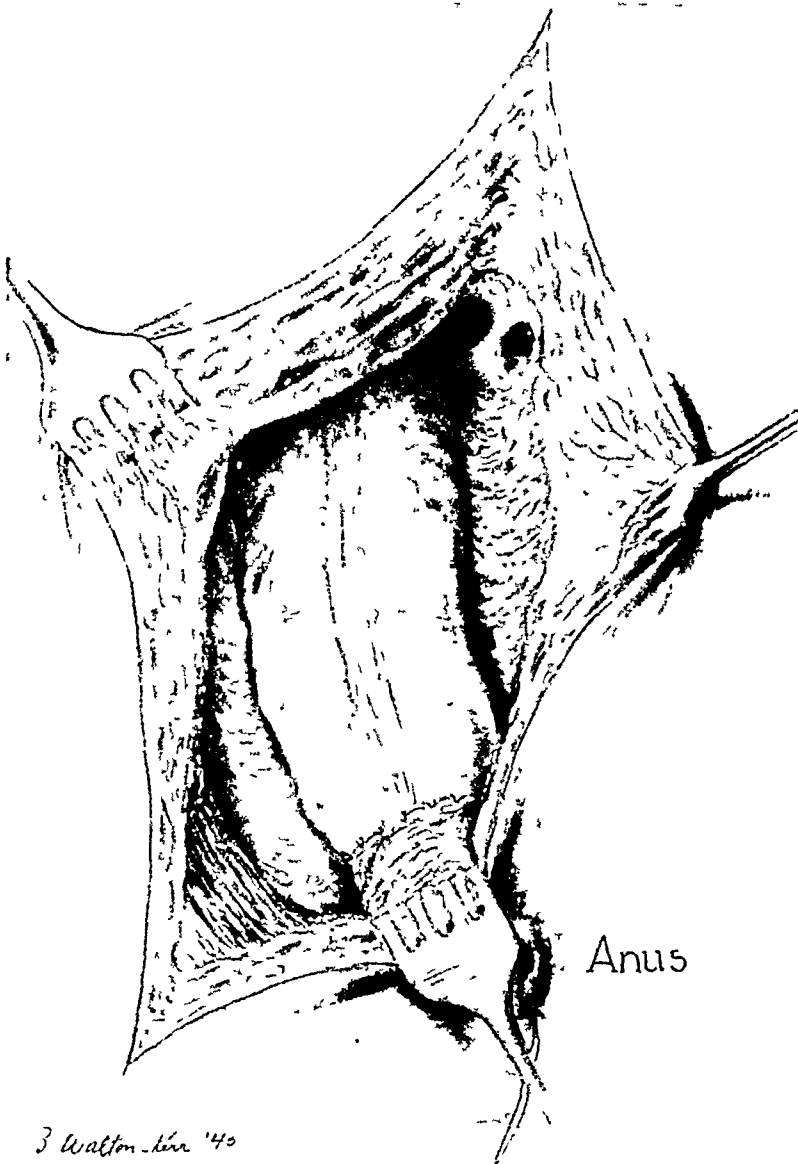


FIG. 7.—The sigmoid is anastomosed to the short stump of the rectum. Because of the danger of sloughing, a complimentary abdominal colostomy is essential.

of the rectum are not in the lowest segment. Bacon estimates, from a study of distribution of rectal cancer in 1,401 cases, that only one-fifth of rectal carcinomas are in the last seven and one-half centimeters of the anorectal canal. Mandl states that in 655 cases, the carcinoma was in the segment up to four centimeters (of the rectum) in 29 per cent, and between four and ten centimeters in 45 per cent. Allowing three centimeters for the length of the anus,

Mandl's figures would indicate that 29 per cent of carcinomas of the rectum are found in the last seven centimeters of the anorectal canal and 74 per cent in the last 13 centimeters.

What significance preservation of the sphincter will have on the recurrence rate is not yet determined. If the mortality rate is tremendously increased by a greater evidence of recurrences following partial resection of the rectum, the operation will again be abandoned in favor of the Miles' operation. If, however, the five-year cure rate is as good with sphincter preservation, it definitely becomes the procedure of choice, for, who would have a colostomy when they can have an equal chance for life without one. The initial reports are favorable particularly that of Babcock and Bacon whose 81 per cent survival rate for three years is not surpassed by that of other procedures.

Even though not yet obvious, it is probably true that the assay of the value of operations with restoration of continuity will have to be made, not for the entire rectum but for different sections of the rectum. Thus, it would be expected that anterior resections with anastomosis may yield better results for high lesions than for low lesions when compared to abdominoperineal resections for similar groups.

Even if recurrences were only slightly more common, preservation of the sphincter may still be justified when surgical judgment, as it should be, considers the value of restitution to normalcy a premium in addition to preservation of life with a colostomy. Thus, though it may be difficult to evaluate mathematically in 100 individuals with cancer of the rectum, the salvage of 40 lives with normal rectal function may be worth the salvage of 50 with colostomies.

A point of great practical knowledge is how low a growth may be removed transabdominally and permit the continuity of the bowel to be established. Undoubtedly several factors influence this answer. The persistence of the surgeon and his technical accuracy will be a great determining factor and the amount of bowel which it is essential to remove beyond the gross end of the growth, is another. For those who are convinced that abdominoperineal resection alone removes enough, resection with anastomosis may seem insufficiently radical, but for those who are inclined to keep an open mind on the entire problem, partial resection of the rectum seems to offer excellent possibilities, not only for curing people with rectal cancer, but of curing them without a colostomy.

#### SUMMARY

Almost all of the rectum may be removed, and continuity reestablished transabdominally. In 20 resections of the rectosigmoid and rectum for carcinoma, restoration was attempted in 13. When the growth was as high as eight centimeters above the external anal outlet, it was removed and the rectum reconstructed transabdominally. This has promise of being the operation of choice for the majority of rectal cancers.

An operation is described for combined abdomino-ischial resection for low rectal growths. The results would seem to justify further attempts.

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## FURTHER OBSERVATIONS UPON IMPERFORATE ANUS\*

DR. ROBERT L. RHODES

AUGUSTA, GA.

WITH THIS MALFORMATION occurring in about one in every 5,000 babies born and over 2.5 million babies annually, 500 or more each year have this defect—that is a sufficient number for us to have a clear-cut plan of action or treatment to give these babies an average chance at a normal life and not subject them to haphazard bungling or consign them to a colostomy life, with all its attendant ills for child and mother.

Such a plan<sup>1</sup> I submitted before this Association 12 years ago, with the report of a case. Incidentally, this girl is living and well, 13 years of age, and has developed normally, with perfect control over her bowels. I did not enter into any discussion or criticism of previous suggestions or methods of treatment but reported a case with the process of reasoning as it progressed and the developed technic. It has been amazing to find so many surgeons who are not familiar with the method and appalling the number of these infants who are literally taken from the delivery room to the operating table and a colostomy established. Thus, my excuse for again bringing it to your attention.

This state of affairs is very largely due to authors of books on Surgery, and contributors to Systems of Surgery, who not only ignore my simple procedure but continue to offer misleading or inaccurate suggestions or statements for the guidance of the surgeon suddenly confronted with this malformation. I found such to be true 13 years ago but was not impressed by the information obtained and proceeded to work out the technic as reported. For instance, David in the current reference works, "Practice of Surgery," published by Prior and Nelson's "Loose Leaf Living Surgery," says "Wangenstein and Rice procure a plain film of the abdomen and pelvis with the child held in an inverted position to determine the outline of the terminal bowel by the gas present in it." It is true that gas rises but it is also true that gravity pulls earthward—the terminal bowel may be pulled one-half to one inch further from the perineum when the child is inverted. I showed a picture taken with the child on its side, with knees firmly flexed against the abdomen to force the terminal bowel as low as possible and I will show in the slides a little later the very definite advantage of this position and the more accurate information derived.

Furthermore, David adds, "if the child is not in good condition, and perhaps in any event in this type of high-lying rectum, a colostomy should be performed as a life-saving procedure, hoping at a later date to establish continuity of the bowel. In this particular situation the prognosis is grave, but

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\* Read before the Fifty-seventh Annual Session of the Southern Surgical Association, December 4-6, 1945, Hot Springs, Virginia.

of paramount importance is the early diagnosis of imperforate anus so that steps may be taken to relieve the obstruction before the devastating effects of a large bowel obstruction are in evidence." My answer to that is that experience has borne out a statement in my first discussion: "We reasoned that the newborn with a sterile alimentary tract could not and would not die of the toxins of intestinal obstruction even after several days," and I might have



FIG. 1.—(This and the following three illustrations are of Case 4). Child held up by its feet. Note how high is the terminal bowel and rounded end.

added that sterilized food and sterilized water, such as are given to babies, markedly delay the establishment of intestinal flora. Such statements frighten one into rushing in too soon. As a matter of fact, it is not the toxins resultant from intestinal obstruction that cause anxiety, as I will show in the report of a most unusual case, but the increasing regurgitant vomiting, with the danger of aspiration suffocation as the abdomen becomes more and more distended. This danger can be markedly avoided by keeping the baby on its ventral surface entirely.

The several points I tried to make, which I now wish to emphasize and to add several additional ones, are (1) that there is no need to hurry, but

give them time to develop all they have, encouraged by giving water and feeding normally; (2) repeated roentgenograms either fluoroscopic or films with the baby on its side and the knees firmly flexed against the abdomen will show the terminal bowel at its lowest point; (3) finger pressure in the perineum towards the terminal bowel will reveal the distance to be covered: (4) small incision to permit the finger to bore its way to the bowel, instead of laying the perineum wide open and thus open a large raw area for secondary



FIG. 2.—Taken immediately after Fig. 1, but with child lying on its side and knees flexed. The projection of the terminal bowel is about one inch lower than in Fig. 1, thus giving much more accurate information.

infection as well as destruction of the sphincter; (5) place the incision in the approximate area of the sphincter and try to cut it in only one place, an advantage of the small incision; (6) when the bowel is reached sweep the finger around it to free it, grasp the lowest point with a clamp and with gentle traction on this, gradually free it all around until it can be brought down as far as possible; (7) if the entire bowel can be brought to the skin surface, open it and suture to the surrounding skin, if only part way, anchor it on the four quadrants to the surrounding muscles, open the end, free and bring the mucosa on down and suture to the skin; (8) because of the danger of skin contraction these cases must be dilated weekly at least, until they are about

one year old; and (9) no anesthesia is required when operating through the perineum during the first week of life.

I never have roentgenograms taken of them until they are 24 hours old; seldom until they are 48 hours old; and never operate until I am convinced that the bowel cannot be made to descend further, or has reached the skin. In some cases this will occur in 48 hours, in others it will not take place until they are four or five days old.

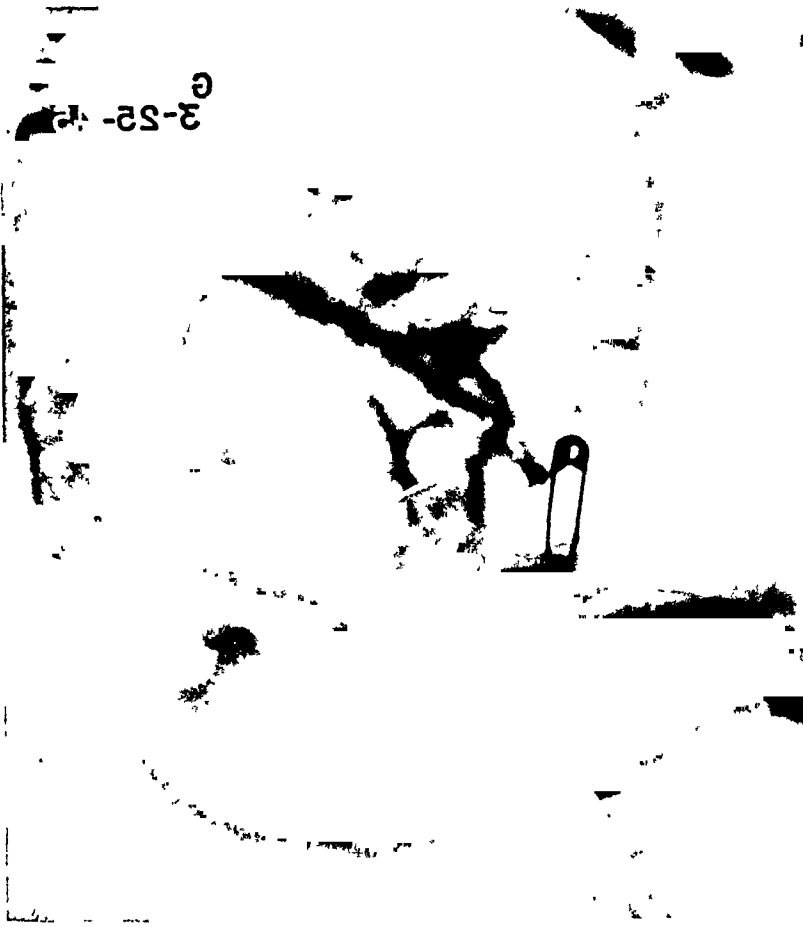


FIG. 3.—Twenty-four hours later the distended bowel has reached the tip of the coccyx, about half an inch lower than Fig. 2.

The appearance of meconium in the urine, indicative of fistula into the urinary tract, with the danger of ascending urinary infection, is not the "bugbear" we have been led to believe, for the simple reason of the lack of intestinal flora at this age. It is, therefore, not an indication for hasty action. Nor will it, in several days, reach sufficient size that it will not heal spontaneously when intrabowel pressure is relieved by appropriate operation. I wish to most emphatically stress my belief that the overwhelming majority of these cases can be reached through the perineum if they are permitted sufficient time to develop or distend their terminal bowel. Perhaps there may be a thousandth case that will require colostomy. A point, here, to remember

## IMPERFORATE ANUS

is to establish the colostomy high in the sigmoid to leave redundant bowel below, in the hope that as the child grows it may develop sufficient length to be carried to the perineum and the establishment of an outlet. Should distention become too extreme, a tube may be passed easily through the nose into the stomach and deflate, or on into the small bowel if necessary. The gas or air bubble in the terminal bowel will not be greatly influenced by the deflation above.



FIG. 4.—Firm finger pressure on the perineum lacks about 1.5 cm. of reaching the tip of the bowel but that the latter can be reached, with a little more tedious dissection, through the perineum than when the bowel is low enough for finger pressure to reach it.

The following case reports have been selected to demonstrate the application of these fundamental principles:

### CASE REPORT

**Case 1.**—Baby R. E. is the only one upon whom I have performed a colostomy since the development of the above technic. The child was born in a neighboring hospital, November 12, 1941, at 10:30 P.M., and was sent over to me the following morning. Roentgenologic studies showed no development of the bowel below the sigmoid, which was redundant, that is, no rectum or anal canal and, in addition, "maldevelopment of the sacral bones and coccyx." When 90 hours old he began to pass meconium in his urine, therefore, we at once established a colostomy, under local anesthesia, because of



the fear of ascending urinary infection. After a short time the meconium disappeared from the urine, and he has developed normally otherwise to date. In several more years we shall recheck him to determine the advisability of attempting to establish bowel continuity to the perineum and later closure of the colostomy.

**Case 2.**—Baby C. T. D., admitted on March 11, 1945, is a "believe it or not" Ripley case, in that at four months of age he had never had a normal movement of solid or semisolid material, and is proof that one does not have to fear large bowel obstruction in these cases. This was somewhat of a "special dispensation child" when he came after his parents had given up all hope of any offspring, discouraged by 14 years of barren life. He was well-developed at birth, weighing 8.5 pounds, except for an imperforate anus, but he had a definite dimple in the anal area. His parents were advised and urged to bring him for operation, but they refused. When three days old, a small fistula appeared near the base of the scrotum through which liquid and gas were evacuated daily. He was breast-fed and exceptionally large at four months of age, weight 16.5 pounds, quite normal in every respect except for the imperforate anus and fistula, which permitted the passage of only a 2 mm. probe. At operation, under light ether anesthesia, a probe was threaded through the fistulous tract into the rectum, a circular incision was made around the orifice and extended in a straight line posteriorly into the middle of the dimple. The fistulous tract was dissected down to the bowel, which was mobilized sufficiently to be brought down until it could be resected above the fistulous communication and its end sutured all around to the skin with numerous interrupted fine silk sutures. Convalescence was uneventful, and when checked four months later, except for the small scar the anal region appeared perfectly normal, his bowels moved normally, not a steady leakage or lack of control, and his mother had already begun to train him in this respect.

**Case 3.**—Baby P. D., born 5:30 A.M. May 30, 1944, normal in every respect except for imperforate anus and no dimple. A roentgenogram, May 31, 1944, showed distended gastro-intestinal tract down to the terminal end of the sigmoid, but no evidence of any rectal ampulla. The next morning distention had extended to about half way down the rectum, but a stricture was evident at the rectosigmoid junction, and a fistulous opening appeared at the middle of the posterior surface of the scrotum through which a small amount of meconium escaped. The urine did not contain meconium, therefore, the fistula did not extend into the urinary tract. By late afternoon the entire rectal ampulla was distended but the stricture at the rectosigmoid persisted. The following morning, June 2, 1944, the stricture had dilated, the rectum was well-distended, down almost to the perineum. Operation was performed at 80 hours age, in the manner of the preceding case. Convalescence was uneventful.

**Case 4.**—Baby G. was born 7:40 A.M., March 21, 1945, without anus or dimple, but in other respects normal. March 23, 1945, a roentgenogram showed distention to rectosigmoid junction; on March 24, 1945, distention had extended to about half way to the rectal ampulla, the end being at the level of the sacrococcygeal junction; March 25, 1945, distention had reached the tip of the coccyx, apparently filling the rectum, but there was no evidence of an anal canal, and firm pressure of the finger tip in the perineum lacked 1.5 cm. of reaching the bowel end. The abdomen was quite distended and he was regurgitating almost constantly, so much so that operation was deemed advisable. It was performed at 3:30 P.M., when the infant was 104 hours old. In this case the bowel could not be mobilized or stretched sufficiently to be brought to the skin but was sutured at four points (quadrants) to the surrounding muscles with chromic catgut, the end opened, bowel contents evacuated, thoroughly irrigated, the mucous membrane freed, brought to the skin and sutured with numerous interrupted fine silk.

Convalescence was uneventful, and his mother brought him in weekly for dilatations until he was four months old, when they moved away. She was supplied with a rubber dilator (Wales bougie), instructed how to use it and urged to do so weekly. She, how-

ever, was very indifferent about it, and at 5.5 months of age brought him back quite distended, because of contracture of the anal skin which was easily dilated, copious evacuation, with much gas, immediately occurred and the distention was relieved. She insisted that the distention had occurred when she began to feed him Pablum. Again, she was indifferent about dilatations and at seven months of age he was admitted to the hospital as a Staff case, enormously distended, his bowels were not moving but he was having some escape of intestinal contents through his urethra. Because he had been my private case I was asked to see him, and found his anus almost completely closed, so nearly so that I had to use a fine-pointed hemostat to find the orifice, which was dilated with the clamp until a rectal dilator could be inserted to fully dilate. With daily dilatations and enemas his bowels moved well, the fistula into the urethra promptly healed, the distention was partially relieved but not entirely until he was placed upon a high protein low starch diet, after which he cleared up without further trouble.

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DISCUSSION.—DR. JOSEPH D. COLLINS, Portsmouth, Va.: I wish to emphasize the important point that Doctor Rhodes made in his paper, namely, that it is not imperative to operate upon these babies immediately. Doctor Rhodes has effectively demonstrated this by his report of the case of imperforate anus which he saw for the first time when the baby was four months old.

I have a case to report which even more strikingly illustrates the point which Doctor Rhodes has brought up. About five years ago a woman consulted me regarding a male baby that was then approximately one year old. She stated that this child had never had a bowel movement. Upon examination I found no evidence of any anus, in fact there was not even a dimple, but there was a small opening in the perineum just posterior to the scrotum which ejected at intervals a very fine stream of black fluid and flatus. This child was well-nourished and, except for the abnormality just described, was apparently a normal child. I advised her to have the baby admitted to the hospital for observation and necessary operation. She stated, however, that the baby had recently been exposed to measles and she wanted to wait until after the period of incubation was over. Of course I agreed.

I saw no more of her until two years ago when she brought the child to me again. He was now a boy four years old, perfectly well-developed and normal in every way with the exception of the absence of his anus. He had a rather large abdomen, and upon palpation masses of fecal matter could easily be felt. His mother said he played the same as her other children and apparently suffered no ill effects, except that at times he would have spells of vomiting, especially if he overloaded his stomach. A plain roentgenogram easily demonstrated the enormously distended colon filled with fecal material. It was not possible to inject this small fistulous opening with barium, but the roentgen ray technician was able to introduce a small fuse wire through the fistulous tract into the rectum, which the roentgenogram showed to be about one inch above the level of the skin. Leaving this fuse wire in the opening and using it as a guide, I dissected out this sinus and found the lower end of the rectum. I then dissected out the rectum, brought it down and sutured it to the skin, after the manner of the old Whitehead operation for hemorrhoids. I was able to find the rudiments of the sphincter, which has functioned fairly well. The child is now perfectly well, with fairly good control.

The mother of this child has had ten children, two of whom had to be operated upon for congenital pyloric stenosis when about six weeks old.

DR. HUGH A. GAMBLE, Greenville, Miss.: I was especially interested in Doctor Rhodes' paper, particularly as to the time that he stated would be safe to delay surgical intervention. Many of the cases we do not see early. I have had three cases; one I saw within 24 hours, another in three days and another about the fifth day.

In the first case the terminal bowel could be reached by blunt section and was opened and sutured to the skin.

In the second the bowel had not, in my opinion, descended low enough for an attempt to be made to reach it from below, and in the third there was a fistulous communication between the vagina and the rectum and also a small opening along the lower border of the sacrum. There was a slight dimple where the anus should have been.

In the second case, in which the terminal bowel was high up, a cecostomy was performed in order to keep the left side of the abdomen clean for future operations. This child disappeared and I have not been able to find what the ultimate outcome has been.

In these cases of imperforate anus the bowel can come down low enough to be reached by blunt dissection from below. Again there are some cases in which the terminus of the bowel is so high as to necessitate either a cecostomy or colostomy. Also, it is often found that there are fistulous tracts joining the terminal bowel with the bladder, urethra or vagina.

In the last case, which I saw about six months ago, there was a rectovaginal fistula, small in size, and also a fistulous tract opening along the lower border of the sacrum. It was not difficult to make an opening where the anus should be, bring the bowel down and attach it to the skin margin. Fortunately, the fistulous tracts have closed spontaneously.

In the after treatment there is a tendency for the skin to contract around the external orifice and it is necessary to continue dilatation over a prolonged period of time.

As Doctor Rhodes has emphasized, I do not think that a moderate delay is of any special significance in handling these cases. In fact, one is in much better position to determine what procedure to adopt after giving the terminal bowel an opportunity to descend as low as possible.

DR. FRANK H. LAHEY, Boston, Mass.: I had hoped that someone else would rise to discuss Doctor Mahorner's paper from the point of view of the effect of procedures to preserve the sphincter ani, such as he and others have described, upon the ultimate nonrecurrence rate; the immediate general mortality rate; and the postoperative complication rate, such as stricture and perianal fistulae.

Mr. Robert Moses, of New York, a short time ago, made a most apt remark in a debate of somewhat acute character. He said: "Now we have a good contentious subject and we can choose up sides and have a contest." About the principles involved in the paper one can only say he has to select his side now and, later, if he is wrong, so much harm will have been done one way or the other that he will regret it. To answer the above questions will take time and cases, but I want, unreservedly, to choose my position now and give the reasons for doing so. I have chosen to continue to support complete abdominoperineal radical resection with a permanent abdominal colostomy, for these reasons: I feel less concerned in a patient with carcinoma of the rectum with conserving his or her sphincter ani than I do with saving his life. I am certain that one has but one opportunity surgically to give these patients a chance to be in the group which does not have recurrence, and that is at the time the first operation is done. It is the completeness, the radicalness and the aggressiveness of this first operation which so positively influences how many cases will be in the five-year nonrecurrence group and how many will not be in this group.

With the above principles in mind and after having dealt with 2,000 of these cases as we have, in fat people, in thin people, in good risks, in bad risks, with small lesions, with large lesions, with associated inflammatory processes and without associated inflammatory processes I do not want to be handicapped by any technical procedures related to pelvic anastomoses and preservation of the perineal sphincter. I do not want to be concerned with whether or not enough loop of sigmoid or descending colon will be left to get it down to the remaining stump of pelvic rectum. I do not want to be limited in any way as to how high I can go in removing nodes along the iliacs, as relates to the blood supply of the sigmoid and descending colon. I know with a colostomy I can take out the entire sigmoid, rectosigmoid and descending colon and make a colostomy in the transverse colon if I want to. By means of this, if I choose to, I can remove nodes as high as the point where the jejunum becomes retroperitoneal.

I became interested some years ago in anterior resection, leaving a small lower segment of rectum behind in high lesions to avoid the necessity of posterior removal,

particularly in bad risk cases. There were so many recurrences in the remaining stump with this operation that we were forced to abandon it.

We have reported our end-results in 1,800 cases of carcinoma of the colon and rectum in which the highest percentage of five-year nonrecurrence rates occurred in those patients with no nodes, no local extension and no blood vessel invasion, 90 per cent. The lowest five-year nonrecurrence rate, 14 per cent, was in those cases in which there was blood vessel invasion. We, therefore, are interested only in a type of operation which fulfills for us three requirements: The removal of the lesion with the widest possible margin of safety on either side of it; the largest amount of node-bearing structures around it; and the widest block removal of adjacent blood vessels.

In my opinion, altogether too much apprehension has been created about a colostomy. Too many of the opinions that a colostomy is so terrible are based upon a palliative colostomy and not a colostomy after a lesion has been removed. We have literally hundreds of patients with good functioning colostomies who wear no bags, who do everything, and who are quite satisfied with their life and existence. A well-established colostomy in a patient who is well educated in its management is by no means the hardship some writers suggest it to be. Much of the energy devoted to popularizing preservation of anal sphincters at the price of limiting the radicalness of the removal of the lesion is based upon the patient's sentimental objection to a colostomy. In my mind this is quite wrong. (1) because the patient's opinion and decision about a colostomy is an entirely sentimental one based upon no knowledge of how well it works and certainly with no experience with what the effect of the accomplishment of retention of his perineal sphincters will have upon his life immediately, his postoperative complications and his ultimate freedom from recurrence of the malignant lesion.

Even when results with this operation at the end of five years are reported, they will still be difficult to evaluate unless groups of cases for both methods in terms of operability rate, how many palliative resections are done and the selectiveness of the cases submitted to these radical procedures are compared.

In my hands, I know of no operation which can be more technically difficult than some of these abdominosacral resections, and when I think of the difficulties I have had with some of these cases to which would need to be added pelvic anastomoses, I cannot avoid the opinion that ultimately these attempts to obtain two things at one time will prove that you never get something for nothing.

DR. HOWARD MAHORNER, New Orleans, La. (closing): We must certainly listen to Doctor Lahey because of his tremendous experience and because of what I think is his unfailing judgment about surgical procedures. I respect his opinion and at the same time I hope for these patients justification for restoring continuity. I do have some sentiment about the sphincter; in spite of a higher mortality rate, reestablishment of continuity may be justified when surgical judgment is tempered with philosophy. It is difficult to measure numerically, but I have an idea that 40 patients living with restored continuity is worth 50 living with colostomies.

# CONGENITAL DEFECT OF THE ABDOMINAL WALL IN THE NEW BORN\*

(GASTROSCHISIS)

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SURGICAL RARITIES are of limited interest. My subject, I hope, proves an exception to this generality. It concerns an unusual congenital defect, with a brief study of its history and etiology, and the record of a procedure for its successful repair. The case is one of gastroschisis with a large congenital defect of the abdominal wall, operated upon 30 minutes after birth; the result is a surviving and normal child, now three and one-half years old.

"Embryology in disorder," according to Ballantyne, is "teratology." With this observation we propose a brief summary of the theories which have been advanced for the occurrence of gastroschisis. Students of antenatal pathology are agreed that amniotic displacement is the most frequent factor in the production of monstrosities. They believe that gastroschisis, like the great majority of the deformities which affect the unborn infant, has an embryologic and amniotic explanation. Since the embryonic period is limited to the interval between the first and sixth weeks of prenatal life, this accident, which is a structural abnormality and not one of growth, originates with the embryo and its environment.

Normally the embryo floats free in the liquor amnii; but if from *scarceness* of the liquor or from adhesiveness of the embryo, or of the walls of the embryonic sac, the amnion comes in contact with and becomes united to the embryo, then that part of the embryo so affected is arrested or distorted in its development, and a malformation results. Although enunciated 30 years ago, in 1905, Ballantyne's theory is both logical and lucid, and we accept it as authority for the etiology of this type of congenital defect. He also cites the fact that the teratogenic pressure on the embryo is not always amniotic. It may be caused by pelvic or abdominal tumors, by deformities of the uterus or narrowness of a tubal gestation sac, by the umbilical cord or even by one part of the embryo compressing another. As surgeons, we face a practical responsibility arising from this embryologic concept. We must impress on our colleagues the importance of removing all pelvic tumors, particularly during the child-bearing period.

The literature of this abnormality is voluminous and unorganized. The subject has been difficult to study on that account, and a part of my purpose in its presentation has been an attempt to re-edit the bibliography for future reviewers. The problem of nomenclature appears promptly, for the very name of this teratologic accident is still undetermined. The best term currently used

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for it is a Greek word, *gastroschisis*, more freely translatable as "belly-cleft," and defined as "a congenital malformation in which the abdomen remains open." It was coined for an abnormality whose occurrence is rare but which has been reported at intervals since the year 1557. In the long uncatalogued annals of this anomaly, many other titles are used to describe it. Cullen prefers "amniotic hernia" for his discussion. For Bernstein's bibliography, only six of 28 references to gastroschisis include the word. Taruffi, faced with difficulties in Italian terminology, was one of the first to coin and use the collective title. In 1894, for his "Storia della Teratologia," he used "gastroschisis" adding many syllables for a proposed "regional nomenclature" of the defect. This he arranged in seven definitive but cumbersome group-heads: (1) Epigastroschisis; (2) epiomphaloschisis; (3) thoraco-omphaloschisis; (4) hyogastroschisis; (5) hypogastroetroschisis; (6) pleurosomataschicis; and (7) holo-gastrostroschisis.

In 1812, J. F. Meckel, the elder, described this defect as "partial fissure of the anterior surface of the body." The majority of German authors have briefed it to "bauchspalten," or "abdominal fissure." Spanish writers describe it as "fissura abdominalis completa." French and Russian literature report "agenesia of the abdominal wall." In English, "eventration," "amniotic hernia," "congenital absence of part of the abdominal wall," "massive ectopia intestinalis," and "nonclosure of the abdomen" are other variations. Besides all these, many cases of gastroschisis are completely lost to reviewers in titles less descriptive. In 1931, Poloyas deplored this fact.

"A complete search of the literature is difficult," he declared, "because there is no standard classification of monsters, which are often incorrectly classified. . . . Cases are hidden in titles which are often ambiguous, "An Unusual Monstrosity," "A Rare Fetal Anomaly."

He concludes his report of a case of "nosencephaly with eventration of the abdominal and chest organs, etc.," with a plea for "standard nomenclature and accurate titles of case reports"—but the difficulty remains.

A full survey of the literature is limited by its undetermined nomenclature. But all reports of this defect which we have found, fall into three groups, easily differentiated, not by *region* but by *degree*. Chronologically, the same groups appear. With rare exceptions, the earlier reports are all fatalities. It is tempting but unprofitable to ask how many of them could have been rescued by more surgical knowledge and better technic.

The exact number of reported cases of this congenital defect, has not been fully catalogued. The first known case, according to Bernstein, was reported by Lycosthenes in 1557; and from that time on, gastroschisis (though rarely so-called) is not uncommon in the literature of teratology.

In the references available for our study of the subject we have found 96 case reports. Sixty-eight of these we find belong in Group I, stillborn monstrosities. Nineteen cases compose Group II, child living at birth, normal except for his abdominal wall defect, but no attempt made to repair it. Group

III includes the nine cases we have found in the literature, including this case report, in which attempt was made to repair the defect.

Into Group I, unhappily the largest, we place all cases reported as impossible to repair. The majority of them concern the necrology of a stillborn fetus, for prematurity is characteristic of gastroschisis. They include extreme teratologic deformities besides the eviscerated organs of the abdomen. Exstrophy has occurred long before delivery and the eventrated organs have grown to enormous disproportions with the empty and shrunken cavity behind them. In all such cases, the report is that there could be no question of a possible closure, or of regeneration of the defective abdominal wall, even if the child had been born alive. For these monstrous infants, according to Kleiner, "an operative procedure is wholly unthinkable." In both of his reported cases he says: "the fetus on account of his malformation is not capable of life; he is solely interesting as an exhibit of pathologic anatomy." However, Group I also includes a number of cases of stillborn gastroschises in which the infant was delivered at full term and normal in all respects besides his abdominal defect.

In Group II, which includes only "simple" gastroschises, the number of cases is much smaller than Group I. A search of many titles, ambiguous and otherwise, is rewarded by the occasional report of an infant born alive and normal except for a defective abdominal wall; but these too have all failed to survive. Their organs were eventrated through the abdominal defect at birth, and no surgical repair was accomplished or attempted.

A chronologic list of the 19 cases described as Group II, in our survey, includes the following authors. We have added the length of time each infant lived.

## GROUP II

Calder, J.	1763	Child lived 4 days
(Unsigned) Report in the J.de Pract. Heill. Berlin	1805	Child lived 58 hours
Ogle, J. W.	1864	Child lived 29 hours
Batalla	1874	Child lived 4 days
Crowther, B.	1878	Child lived 15 hours
Kramarenko	1888	Child lived 48 hours
Todd, G. B.	1895	Child lived 15 days
Schmidt	1900	Child lived 4 days
Johnston, J. A.	1903	Child lived 48 hours
Tate, M. A.	1903	Child lived 4 days
Lee, D. F.	1907	Child lived 28 hours
Forsyth, C. B.	1908	Child lived 26 hours
Das, K.	1908	Child lived 10 minutes
Aranow	1910	Child lived 30 minutes
Bott, Stanley	1911	Child lived
Fletcher, M. A.	1928	Child lived 14 days
Kleine, H. O.	1929	Child lived 15 minutes
Hyde, Charles T.	1930	Child lived 16 hours
Purdy, W. and Stofer, B. E.	1934	Child lived 8 days
Krauss, F.	1936	Child lived 2 hours

There are 19 cases in this group. They have lived from a few minutes to eight days, and there is evidence of the striking hardihood and will-to-live in the newborn in the eager attempts made by these abnormal infants to take nourishment, and also in their normal excretory functions. The causes of

death are variously reported as peritonitis, gangrene, pneumonia, dehydration, exhaustion. To these we may add failure to make surgical repair of the defect.

For one of these cases, Forsyth, in 1908, reports a half-hearted attempt to replace an infant's extruded stomach and small intestines inside the abdomen. But he did so only to make the monstrosity "more presentable" to its parents. In doing this he expelled a large quantity of yellow amniotic fluid from the child's mouth and nose, after which the attending physician resorted to artificial respiration and the baby began to breathe regularly and cried lustily. Bowels and kidneys functionated several times and the child nursed, but kept up a whining cry until it died after 26 hours. This is the only attempted surgical repair which is recorded among these fatal cases of the abnormality.

Group III, though the smallest, is by far the most interesting part of our survey. It includes all the cases we have found in which attempts to repair the defect were undertaken. In six of the nine cases found in this group, the result has been a living and normal child.

William P. Hogue, of West Virginia, in 1887, reports the first successful repair of this congenital defect. His patient was a Negro male infant, delivered by a midwife. He was called to see it an hour and a half after birth. The child had a small defect in the abdominal wall, an opening one by one and a half inches in diameter in the region of the umbilicus. Through this opening the infant's bowels passed out in a mass reaching down to the pubes. The edges of the defect were smooth and glossy. He closed the opening with strips of plaster put on straight and diagonally. At the end of five weeks, he was surprised to find the child thriving, with his opening entirely and permanently closed. The report ends with the fact that the child is now living and about eight years old.

Benedict's case, in 1895, is erroneously entitled "An Enormous Congenital Umbilical Hernia." It reports a protrusion of the abdominal viscera through an opening four inches in diameter in the abdominal wall. The color of the mass at birth was a "dark bluish-black," and the covering was so thin that the movements of the viscera within could be plainly seen. Fifty-three hours later, Benedict did a rather extensive repair operation, under chloroform, which lasted 50 minutes. He reports: "The approximation was made upon the subcutaneous surface rather than upon edge of skin. This was held together by three silver pins, an inch long, wound with silk in the figure-of-8 way, and immediate apposition obtained by black silk interrupted sutures."

Three weeks later, when his report was written, the child was healed and was apparently normal and well.

Caffier's case, reported in 1929, had a defect "the size of a man's cuff" through which the abdominal contents protruded. Only about one-quarter of this mass was covered with a peritoneal "veil." It is interesting to note that conservative treatment only was used. This consisted of alcohol poultices strapped over the defect's protruding contents. The eventration gradually subsided into the abdominal cavity. After three and a half months the defect was entirely healed over, leaving only a slightly protruding herniation.



Dr. Gamble's case, reported in 1930, describes a white male born with complete absence of the abdominal wall. The defect was 3.5 inches in diameter and covered with a thin translucent membrane. During delivery the stomach and liver were both totally eventrated through this defect. The defect was repaired by a modified Mayo operation for umbilical hernia. During operation it was noted that there was almost complete absence of the suspensory ligaments of the liver, and in order to maintain the liver in position, it was necessary to suture the round ligament to the costal margin. An excellent closure was effected. There was little shock, and the baby made an uncomplicated recovery. Reported at seven months



FIG. 1.—Artist's sketch of defect at birth.

Koon's case had a two-inch defect through which all the intestines extruded. It was delivered at home and had to be removed some distance to the hospital, where a surgeon attempted to repair the defect under novocaine and a few drops of ether. Through-and-through sutures were used. The patient did well until the fourth day when it became dehydrated and died.

Williams reports a case of amniotic hernia which was not referred to the Surgical Department of the Medical College of Virginia until two days after birth. The child was a Negro male, well-developed and well-nourished, with no other abnormalities besides a three-inch defect of the abdominal wall. The contents of the abdomen were covered by a transparent membrane. Under ether anesthesia, an incision was made about one-quarter of an inch from the

skin edge leaving this small circle of skin attached to the membrane. The skin was undermined around the whole defect without disturbing the muscles, the excessive stump of the umbilical cord was removed, and the skin easily closed down with interrupted sutures. The baby rapidly declined and died 12 hours later.

Dry reports a difficult delivery. The child was vigorous and normal except for his large defect of the abdominal wall with complete eventration of liver, stomach, small intestines, and colon. An attempt was made to return the exposed contents into the cavity by plastic methods, but the infant succumbed the same day.



FIG. 2.—Condition at end of first week. (Prompt growth of epidermis from the outside; the amniotic covering is necrotic.)

Watkins' case, when delivered, had a large reddened mass of its viscera hanging from its abdomen. This had been eventrated through a slit, about one inch long, just to the left of the base of the umbilical cord. The viscera were the small and large bowel, both of which were thick, leathery, cyanotic and larger than normal. The opening was enlarged to two inches in the midline, when the child was 30 minutes old, and the viscera were placed in the abdominal cavity with some difficulty because of their size. The wound was closed with through-and-through sutures. Dehydration was combatted early and frequently, and 16 days later the child was dismissed from the hospital healed and gaining normally.

In making this study we have been careful to differentiate such cases from reports of true umbilical hernia, which is a far more more common abnormality of the newborn, as well as from the condition known as omphalocele or exomphalos.

William Fear's case of eventration at the umbilicus is a type which has

also been confused with the literature of gastroschisis. In this case, reported in 1878, the small intestines, practically the whole of the colon and the pyloric end of the stomach protruded through a long slit in the cord. Repair was made, the organs were replaced and the child lived. A notable case, but not pertinent to the literature of defects of the abdominal wall.

**Case Report.**—Baby H. born July 11, 1942

**Mother's History:** Mrs. H., age 26, weight 156, admitted to Johnston-Willis Hospital 8:30 A. M., July 11, 1942, a patient of Dr. M. Pierce Rucker. Diagnosis: Term pregnancy; vertex R. O. A

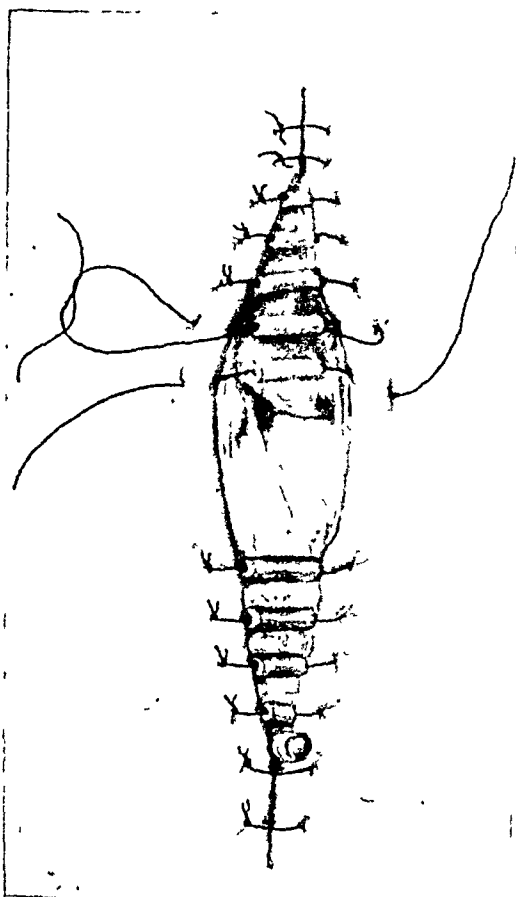


FIG. 3.—Repair made immediately after birth. Note: incision not completely closed, due to tension.

**Previous History:** Menses appeared at 12; occur every 28 days, lasting 3 to 5 days. Other history negative. No abnormalities, no twins on either side of family.

**Marital History:** Married October 1, 1931. Has had three children previously. No miscarriages. First child born July 12, 1932, at 7.5 months. Labor severe and prolonged; eclampsia. Second child born September 11, 1933, at 6.5 months; lived only a few minutes. Third child born May 14 1939, at six months; stillbirth.

**History of this Pregnancy:** Last menses October 7, 1941, lasted five days. Has had a bearing-down sensation; perspires freely; cough. Appetite is good. Has nocturia, gas, no dysuria, no nausea, no backache. Appears well-nourished; no skin eruption; no edema; no varicosities. Wassermann test, negative. Mental attitude good, but somewhat nervous about the outcome of this birth because of two previous deliveries. B.p. 136/82.

**Labor History:** Patient admitted to hospital for induction of labor, having taken quinine and digitalis since June 25, as directed by Dr. Rucker. Membrane ruptured with uterine dressing forceps at 9:47. Pains began at 10:30 A. M. Duration of labor five hours, 50 minutes. Anesthetic: morphine gr. 1/6; sodium amytal, gr. 6, hyoscine, gr. 1/100; pentothal 750 mg. Local, with 1 per cent novocaine and adrenalin.

When the cervix was fully dilated and the head had rotated anteriorly, Linkart forceps were slipped on and an easy extraction was done. No cord was about the neck, external rotation was to the right. Right lateral episiotomy was done.

**Baby's History:** Delivered without difficulty at 4:17 P. M. Wt. 5 lbs. 11.75 oz. During delivery a large defect was noticed in the anterior abdominal wall, and care was taken lest the thin covering over the exposed abdominal viscera should be punctured. (This careful procedure had a most beneficent influence on the repair of the defect.) Saline compresses were placed on the abdomen and the baby was sent immediately to the Surgical Department.

**Findings at Operation:** General appearance and features were entirely normal except



FIG. 4.—Result at three-and-a-half years.

GROUP III: REPAIR of DEFECT						
Reported by	C.	S	YEAR	SIZE OF DEFECT	TIME-LAG BIRTH TO OPERATION	RESULT WHEN REPORTED
1) HOGUE, W.P. CHARLESTON W VA	N.	M	1882	1" x 1¾"	1½ HRS.	CHILD LIVING and NORMAL 8 YEARS OLD
2) CAFFIER, P. BERLIN	W.	M.	1929	6 3".diam	BRIEF. (CONSERVATIVE TREATMENT)	CHILD LIVING and HEALED AFTER 3 MONTHS
3) GAMBLE, H A GREENVILLE MISS	W.	M	1930	3½".diam	NONE	CHILD LIVING and NORMAL AFTER 7 MONTHS
4) WILLIAMS, C. RICHMOND VA	N.	F.	1930	3". diam	2 DAYS	CHILD DIED, 12 HOURS LATER
5) DRY, FM. ILLINOIS	W	F.	1934	LARGE	BRIEF	CHILD DIED, SAME DAY
6) KOONS, FW. KANSAS	W		1934	2". diam	X HOURS	CHILD DIED, 4 DAYS LATER
7) WATKINS, WAYNESBORO VA	W.	M	1943	SLIT, 1" long	½ HOUR	CHILD LIVING and NORMAL AFTER 5 WEEKS
8) JOHNS, F.S. RICHMOND, VA	W.	M.	1945	10 cm long 11 cm wide	½ HOUR	CHILD LIVING and NORMAL AFTER 3½ YEARS
9) BENEDICT, SC ATHENS, GA	W.	M.	1892	4". diam.	53 HOURS	CHILD LIVING and NORMAL AFTER 3 WEEKS

FIG. 5

for the abdominal defect. This was 11 cm. wide, 10 cm. long, extending from just below the xiphoid to some distance below and including the umbilicus. This large gastroschisis was entirely covered by a thin translucent veil-like membrane which had not been ruptured. Through the covered aperture the liver, gallbladder, stomach, colon and small intestines protruded above the surface of the abdomen.

The operation was carried out under general ether anesthesia. Local anesthesia would not have been suitable in this case, for which complete relaxation was essential.

The first procedure was to get the abdominal contents back inside the cavity, so that an attempt at closure could be made. At first, when the organs were forced back gently into what should have been their normal position, the baby would stop breathing. Hoping to improve this situation by exerting very gradual pressure, I put in silk ligatures one-half an inch back on the skin at the upper and lower ends of the defect. Then pulling the sides together very gradually, I attempted to close the opening. In doing this the folds of the unruptured peritoneum were left as a permanent over-all covering. The upper and lower part of the defect could be pulled together without too much tension. In the center, where the defect had been 11 cm. wide, a space at least 2.5 cm. across was left without closure. Adhesive strips were placed over the entire length of the "wound." A dressing was applied and the baby was returned to the nursery.

The postoperative course was uneventful, CO<sub>2</sub> and O<sub>2</sub> were given during the first night and following day. Lactose feedings were begun and retained. Normal saline was given subcutaneously and some diluted breast milk was given on the second postoperative day. On the fifth day he was put to the breast. Fifty cubic centimeters of plasma, (from his father's blood) were given on the 6th, 7th, 8th, 9th and 11th days. The baby's weight increased satisfactorily, and he left the hospital after 13 days, weighing 6 lbs. 5 oz. The entire strapping was kept on for about six weeks, or until there was complete granulation under it.

COMMENT.—In the above case report, three facts contributed to its successful result: (1) The case was reparable, *i.e.*, the organs were not entirely eventrated through the defect, and the abdominal cavity while shallow was nearly sufficient to contain them. (2) The defect though very extensive was covered by an unruptured peritoneum, and this covering was not injured or disturbed during the repair operation. (3) There was only a brief time-lag between delivery and surgical repair.

A careful delivery by a competent obstetrician is of utmost importance in all cases of reparable gastroschisis. The essential presence of an unruptured peritoneum depends upon such skilled and able handling. Equally important is the care that must be exercised during operation to avoid puncturing or tearing this thin peritoneal covering over the abdominal viscera. Meticulous care must be used in putting in the interrupted sutures to avoid any injury to the exposed peritoneum, in order to ensure an aseptic repair so far as the peritoneal cavity is concerned. As Williams states: Immediate operation, before this covering has become hard and friable, is also of primary importance.

In the application of interrupted, nonabsorbable ligatures, no attempt was made to freshen or free the borders of the defect before closure. They will heal without this additional surgery, which could well affect the mortality of such cases.

The occurrence of this congenital defect is rare, but, as shown in the literature, it does occur. And when it happens we must be prepared to take

care of it promptly and efficiently, with a minimum of surgical procedure. Delay or failure to operate is fatal even in the less serious cases.

This defect was further reinforced by Dr. William Moncure, Salisbury, N. C.

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\* is Group I

\*\* is Group II

\*\*\* is Group III

DISCUSSION.—DR. CARRINGTON WILLIAMS, Richmond, Va.: All these congenital abnormalities bring out a number of points of interest. Whether the theory of adherence of amnion to the peritoneum is correct I do not know, but it seems logical to think that, along with other abnormalities in the midline of the body, the trouble is due to failure of the mesodermal tissue to unite. Operability of these infants, of course, depends entirely on the degree of herniation of viscera through this thin layer and, unfortunately, in a great number of cases the liver is so large that closure is impossible. I feel responsible for the death of one child. You could look into the abdomen and see the various abdominal viscera. I made the mistake of putting off operation for 12 hours and, during that period, being a curiosity, it was viewed by a number of people and when it came to operation the membrane was greenish; and the child died of peritonitis after operation. Doctor Johns operated 30 minutes after birth and this demonstrates the most important thing, particularly around a medical school where everyone wants to see it. The rectus muscles in the baby I operated upon were intact, but widely separated. They should be brought together if the defect is not too great.

DR. HUGH A. GAMBLE, Greenville, Miss.: When I was asked by Doctor Johns to discuss this paper I felt there was little I could add and when I had read it I knew that there was practically nothing. I feel that the Association is to be congratulated on Doctor Johns' assembly of this complete bibliography of this rare condition. We do not know what causes it, but I have been inclined to agree that it is failure of union between the mesoblastic layers of the abdominal wall.

I have seen only one case 30 minutes after birth. The membrane covering the opening into the abdomen had ruptured and whenever the baby would cry the stomach and liver would pop out. This child had to be given a general anesthetic. It may be best, as Doctor Johns has suggested, not to disturb the translucent membrane. In the case I saw, the membrane had been ruptured and I excised it. The opening was closed by a modified Mayo operation; first, bringing the upper borders obliquely across the defect and, second, closing the remainder of the defect by suturing the lower border to the upper edges of the wound. It is impossible to use the overlapping flap as in the Mayo operation, as it is both impractical and impossible, because of the thinness of the abdominal wall, to dissect up flaps. The walls which are lined with peritoneum are sutured, peritoneum to peritoneum, with interrupted nonabsorbable material.

This child had primary union and an uneventful recovery. He is now 16 years of age, takes part in all sports and has had no complications, except possibly one, as a result of this congenital defect. Last summer while on a fishing expedition he was taken suddenly ill with an acute attack of appendicitis and was carried to a nearby city where an exploratory operation was performed. I have been told that the appendix was never located, and I have often thought that this was due to probable nonrotation of the large bowel, because the surgeon who performed the operation was an exceptionally capable man and there must have been some abnormality present to prevent the locating of the appendix.

In my opinion early treatment with closure of the defect is essential, because the longer one delays the more necrotic the covering membrane becomes and the greater the danger of infection. As someone has said, these cases should be taken from the delivery room to the operating room. If you fortunately get them shortly after birth it is remarkable how firm a wall one can get by simply suturing the peritoneal lining to peritoneum with a through-and-through nonabsorbable suture.

DR. H. M. SCHIEBEL, Durham, N. C.: I would like to add an additional case to Doctor Johns' series, which I happen to have had about 11 months ago and have not yet reported. It was entirely similar to the ones described—perhaps a little more like Doctor Gamble's case. The defect was five centimeters in diameter, but rose particularly high above the abdomen, so that almost all the right half of the liver, the gallbladder and a part of the duodenum were visible outside the abdominal cavity and covered by a thin translucent membrane. It was closed in layers with cotton sutures after dissecting away the membrane, as described by Dr. Gamble. The child was seen one-half hour after birth, and was operated upon immediately. Recovery was uneventful.



DR. WILLIAM B. MARBURY, Washington, D. C.: In reporting this case I feel a little like the country doctor whom Dr. Sandy Moore says you can always tell because he has his pockets filled with pencils, a little horse manure on his heels, and an interesting case to report.

My interesting case is one that I saw during the past year. This baby was born during the wee small hours of the morning—as most of them are—and I saw it in the forenoon along with the pediatrician and obstetrician. It had a large defect of the abdominal wall (omphalocele) and though we knew a repair was necessary we were not sure about the optimal time for operation. The pediatrician thought we should wait and build the baby up a little, but the obstetrician and I thought he should probably be operated upon as soon as possible. After consulting Ladd and Gross' book "Surgery in Infancy and Childhood," we learned that these cases should be removed from the delivery room to the operating room.

The defect in this case was about eight centimeters in diameter and one could look through the clear amniotic membrane and peritoneum as through a window, and see the liver and intestines on the inside. This condition changed after some hours and at the time of operation the membrane had become quite opaque. Also, in the hours that elapsed between birth and operation there was a definite increase in size. Each time the baby cried there was a protrusion which seemed to increase the hernia.

Under ether anesthesia, an incision was made in the skin about a quarter of an inch from the amniotic membrane. The sac and cord were removed and the umbilical vessels were tied off. The adhesions to the liver were fairly firm and caused some bleeding when they were freed. The skin and peritoneum were sutured with interrupted silk, with no effort to bring the fascia together.

Ladd and Gross warn against making the closure too tight, stating that it may embarrass respiration or cause pressure on the vena cava with circulatory disturbance. They report 22 cases, 12 of which died; two of these were not operated upon and both died. Many of these cases are associated with other congenital anomalies. This baby had, besides the omphalocele, two inguinal herniae. Except for being a rather difficult feeding case, when last seen he was doing very well.

This reminds me of something I heard in this Association a few years ago. The essayist said that the only way to kill a new-born baby was to cut its throat. I believe this was not meant to be taken too literally, but it does emphasize the fact that babies stand operation well, and there seems to be a definite biologic tendency to live and not to die.

DR CHARLES HUGH MAGUIRE, Louisville, Ky.: In line with Doctor Johns' review of this subject, it is a relatively uncommon condition and, of course, surgically important. I have another case that could be reported but time does not permit. There is a technical point that has been brought out by Ladd and Gross in their splendid book, that has been very satisfactory in closure of the abdomen in infants after repair of diaphragmatic herniae or abdominal wall defects.

We had a youngster with almost complete absence of the left diaphragm, and the stomach, spleen, left lobe of the liver and a large part of the small bowel were in the left pleural cavity. We repaired the diaphragmatic defect with difficulty and, when an attempt was made to close the abdomen, there was so much tension that we knew it would probably break down our repair if the organs were replaced in the abdomen, and the abdominal wall sutured under tension. The skin was dissected up from the rectus sheaths for a distance of four to five centimeters laterally, and the skin flaps were approximated with interrupted silk sutures. No effort was made to close the rectus muscle, peritoneum, or rectus sheaths. The youngster was returned to bed and ten days later was brought back to the operating room; the skin silks removed; a few adhesions between the rectus muscle and the small bowel were freed and an easy closure of the abdomen in layers was accomplished.

DR. FRANK S. JOHNS, Richmond, Va. (closing): I want to emphasize two things which I think contributed to the successful repair of this case of gastroschisis. First, the surgical repair of the defect was carried out immediately. There was only one-half hour delay from birth to operation. Second, time was not wasted in an effort to

undermine the skin around the defect. As seen in this case, healing will be complete by simple closure. To "freshen the edges" of the walls of the defect is to invite infection; and it is also possible that this unnecessary procedure may result in the further disaster of evisceration after operation.

Nineteen babies have been recorded in the literature who were normal in all respects except for a defect in the abdominal wall. All 19 died without any attempt made to repair the defect, and we can be sure that the majority of such cases are never reported. I would direct attention to this rare and reparable congenital anomaly. For these unfortunate but viable infants, an immediate and meticulous though simple surgical procedure is required.

# GANGRENOUS SUPPURATIVE APPENDICITIS

FORTY-EIGHT CONSECUTIVE CASES WITH REMOVAL OF THE APPENDIX AND  
COMPLETE CLOSURE OF THE WOUND, WITHOUT A DEATH

E. DUNBAR NEWELL, M.D.

CHATTANOOGA, TENN.

IN 1929, I wrote a paper, entitled "Peritoneal Drainage, with especial Reference to Drainage or Nondrainage Following Appendectomy when the Appendix is Ruptured." This paper was read before the Southern Surgical Association. There were 56 cases in all that I had operated upon individually. Twenty-three of this series of cases of suppurative appendicitis had free pus in the peritoneal cavity. I closed the peritoneal cavity without drainage and had no deaths. In 33 of these cases of suppurative appendicitis with free pus in the peritoneal cavity, I used drainage in the peritoneal cavity and had eight deaths. In eight of these peritoneal-drainage cases the appendix was not removed. Three of the eight deaths occurred where the appendix was not removed. This gives a mortality rate among these 33 cases, where drainage was used, of 24.2 per cent.

My observation at that time was: (1) that patients with peritoneal drainage had a longer convalescence, with a much longer stay in the hospital than patients without peritoneal drainage; (2) that the complications were more severe and more frequent where there had been peritoneal drainage than in cases without peritoneal drainage. At that time my rule for using or not using peritoneal drainage was to close the peritoneum without drainage if all necrotic tissue could be removed and all bleeding controlled; if I felt that I could not remove all the necrotic tissue without too much trauma and could not completely control bleeding without a gauze packing, then I used drainage.

In a paper that was read before the last meeting of the Southern Surgical Association, in Hot Springs, Virginia, by Dr. T. B. Aycock, of Baltimore, on "The Effects of Sulfonamides on the Mortality Rate in Acute Appendicitis," he reports on a survey of 1151 consecutive patients that were diagnosed acute appendicitis and were operated upon at the Baltimore City Hospitals, extending over a period from January, 1935, until May 1, 1944. Six hundred and fifty-one of this series were operated upon prior to June 19, 1940, with a resulting mortality rate of 5.2 per cent, and 500 were operated upon since June 19, 1940, with a resulting mortality rate of 1.2. Since 1940, sulfonamides have been used in the contaminated peritoneal cavity. Prior to June, 1940, no sulfonamides were consistently used either systemically or locally.

In reviewing my own cases since July 24, 1942, I have personally operated upon 202 cases of acute appendicitis with no deaths, and in which no sulfonamides were introduced into the abdominal cavity. During this same period I

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\* Presented by title before the Fifty-seventh Annual Session of the Southern Surgical Association December 4-6, 1945, Hot Springs, Virginia.

have operated upon 48 cases of acute suppurative appendicitis with free pus in the peritoneal cavity, with no deaths. In every instance of these suppurative appendicitis cases five grams of sulfanilamide powder were placed in the peritoneal cavity around the cecum and in the area where the appendix was removed. In 11 of the 48 cases penicillin was used in large doses. Whole blood transfusions were given frequently; no food was given by mouth for the first three days—the patients were given either blood transfusions or intravenous glucose solutions. In my absence, my assistant used penicillin in the abdominal cavity of one case. Several months later the patient developed intestinal obstruction and, at operation, I found a great mass of adhesions around the area where the penicillin had been introduced. The patient recovered from his second operation. In every instance, the appendix was removed, notwithstanding the fact that there was an abscess or not. No patient with a ruptured appendix was refused operation, regardless of his general condition or the length of time from the onset of his attack. In other words, I have operated upon every case of ruptured appendix that was referred to me, and have removed the appendix since July 24, 1942. Formerly, I did not remove the appendix from an abscessed cavity if it was difficult to remove it, but put in a drain and waited until later to remove the appendix. Since I have been using sulfanilamide with such apparently excellent results, I do not hesitate to remove the appendix even in the presence of an abscessed wall, where often it is difficult to remove the appendix; and in all but one case, no drainage was used, and in all the cases the abdominal wound was closed completely, in layers. The drainage case was one small soft rubber tissue drain placed in the lower end of the wound, but the wound was otherwise completely closed in layers. The patient was a doctor and before operation had insisted that I use a drain. This is the only case that developed a postoperative hernia. Formerly, I closed the peritoneum completely without drainage but did not close the muscle, fascia and skin until several days later. There was only one residual abscess, and this was opened and drained through the cul-de-sac.

In five of these cases the duration of the attack before operation was four to six days, and in a large majority of the series the patients were operated upon on the third day after the onset of the attack. The educational program which we have conducted in this area, against the use of purgation in patients having abdominal pain, has evidently been successful, as very few of these cases had had violent purgation. Formerly, most of our cases from the rural areas had had violent purgation before they came to the hospital. I think that the absence of violent purgation probably has been an important factor in lowering the mortality rate of my operative suppurative appendicitis cases.

# AN INVESTIGATION OF THE RÔLE OF CHEMOTHERAPY IN WOUND MANAGEMENT IN THE MEDITERRANEAN THEATER\*

CHAMP LYONS, M.D.

NEW ORLEANS, LA.

IN A PREVIOUS REPORT<sup>1</sup> which summarized the early surgical experience with penicillin in the United States Army the inability of sulfonamides<sup>2</sup> and penicillin<sup>3</sup> to sterilize dead tissue and sequestra was established. It was concluded that a program of whole blood replacement and systemic penicillin therapy made it safe and practical to undertake surgical operations *at a time of election* in the management of wounds with established infection. The elective operation was limited at first to excision of devitalized tissue and removal of sequestra ("wound revision"). Primary closure after "wound revision" for established infection was contradicted by the observed incidence of anaerobic cellulitis. The wounds had to be left open to prevent the growth of proteolytic anaerobes in residual blood clots and tissue devitalized by surgical trauma and ligature. Even these open wounds were not entirely free from suppuration in spite of continued systemic penicillin therapy with or without additional local applications of high concentrations of the drug. The etiologic organisms in the suppuration of open wounds were found to be *Ps. aeruginosa* (pyocyanea) and *B. protus*. The infection was clinically identical with the "injury necrosis"<sup>4</sup> and the "gram-negative pus"<sup>5</sup> of other observers. It was found that repeated local dressings increased the intensity and the incidence of gram-negative bacillary infection, but such infection did not preclude successful secondary closure by suture or skin graft ("reparative surgery").<sup>1, 6, 7, 8</sup>

At this stage of the investigation the Surgical Consultants Division of the Surgeon General's Office arranged for the overseas exploitation of the possibilities of the reparative program of wound management. Indecision as to the ultimate success of this program prompted a thorough investigation of the whole problem of wound suppuration. It is the purpose of this report to outline the observations and conclusions of the program as undertaken in the Mediterranean Theater.

An unusual opportunity for the study of wounds of the extremity was afforded by the winter campaign in Italy during the early months of 1944. Casualties were received in well-established Base Hospitals located at a relatively short distance behind two static Combat Zones. The vicissitudes of evacuation were fairly constant and hospital organization became standardized on a semipermanent basis. The proximity of the Base Section in Naples to

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\* An abstract of a report in the Essential Technical Medical Data, Mediterranean Theater of Operations, October, 1944. Read before the Fifty-seventh Annual Session of the Southern Surgical Association, December 4-6, 1945, Hot Springs, Virginia.

Fifth Army hospitals in the Forward Area provided an opportunity for direct exchange of information between Base surgeons and Forward surgical groups responsible for the care of a particular patient.

In the Cassino sector the fighting was in mountainous terrain. The weather was cold and wet. Casualties were transported by litter relays down the mountains to Clearing Stations for *triage* and transportation to Field and Evacuation Hospitals. Evacuation from Forward Hospitals to the Base Section was by ambulance and hospital train.

In the Anzio sector combat troops lived in fox-holes on a coastal plane. The weather was wet but less severe than in the mountains. Forward Hospital facilities were within the trajectory of heavy artillery fire and subject to danger from stray shells and air raids. It was necessary for these installations to be "dug in" to a depth of four to six feet. Evacuation to the Base Section was by boat (often LST) and sometimes proved a rigorous experience.

One milliliter "booster" doses of tetanus toxoid were given to all casualties without apparent exception. First aid administration of sulfanilamide powder locally and of sulfadiazine orally at the time of wounding was irregular. On the other hand, all except the most trivial casualties received 4 Gm. of sulfadiazine daily during the first few days after initial surgical management of the wound. Local implantation of sulfanilamide in excised wounds was widely but not universally practiced. In Base Section Hospitals oral sulfonamide therapy was reserved for the indication of established sepsis. Inspection of wounds on open wards without gloves or masks was common practice. Sulfanilamide powder was dusted into wounds at the conclusion of such dressings in many, but not all, hospitals.

There can be little question that there was the usual seasonal increase in the incidence of infection during January, February and March, 1944. Hemolytic streptococcal infection tended to be locally necrotizing rather than invasive.

#### BACTERIOLOGIC INVESTIGATIONS\*

The routine taxonomic classification of all bacteria in war wounds is admittedly an impossible task.<sup>9</sup> However, it was felt that complete bacteriologic study of a few wounds was essential to any analysis of wound suppuration. Details of the technical procedures are reported elsewhere.<sup>10, 11</sup> A single wound was selected for study in each of 36 patients. Twenty-seven wounds were grossly infected and nine clinically "clean." The time from injury to first culture varied from two to 45 days. Approximately seven months were required for completion of this bacteriologic study.

A survey of this sort must of necessity remain incomplete. At least two strains of fusobacteria were recognized in smears or early cultures and were lost on subculture. No spirochetes were recognized. Other bacteria were so

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\*The bacteriologic laboratory was under the immediate direction of Lt. Robert Rustigian, Sn.C., A.U.S., to whom the greatest credit is due for accomplishment of this phase of the study.

TABLE I

<b>I. <i>Streptococcus</i>:</b>	
A. Beta hemolytic:	
1. Lancefield group A.....	4
2. Lancefield group C.....	1
3. Strains "lost" in stock culture.....	2
B. Alpha hemolytic.....	1
C. Nonhemolytic:	
1. Enteric group:	
a. Aerobic.....	13
b. Micro-aerophilic.....	2
2. Undifferentiated group:	
a. Aerobic:	
(1) Simple.....	5
(2) Fastidious.....	1
b. Micro-aerophilic:	
(1) Simple.....	3
(2) Fastidious.....	8
c. Anaerobic:	
(1) Proteolytic.....	5
(2) Nonproteolytic.....	1
<b>II. <i>Staphylococcus</i>:</b>	
A. Hemolytic:	
1. <i>Staph. aureus</i> .....	13
2. <i>Staph. albus</i> .....	0
B. Nonhemolytic:	
1. <i>Staph. aureus</i> .....	1
2. <i>Staph. albus</i> .....	3
3. <i>Staph. (nonpigmented)</i> .....	2
<b>III. <i>Micrococcus</i>:</b>	
A. Aerobic.....	
1.....	1
B. Microaerophilic.....	
1.....	11
C. Anaerobic:	
1. Proteolytic.....	3
2. Nonproteolytic.....	18
<b>IV. Aerobic gram-negative bacillus:</b>	
A. <i>Proteus</i> :	
1. <i>Pr. vulgaris</i> .....	1
2. <i>Pr. mirabilis</i> .....	1

TABLE I—(Continued)

B. <i>Pseudomonas</i> :			
1. <i>Ps. aeruginosa</i> (pyocyanea).....			4
C. Coliform bacteria:			
1. <i>Aerobacter</i> .....			8
2. <i>Escherichia</i> .....			2
D. Paracolon bacteria:			
1. Paracolon <i>Aerobacter</i> .....			4
2. Paracolon <i>Escherichia</i> .....			2
E. Unidentified bacteria:			
1. Mucoid.....			3
V. <i>Clostridium</i> :			
A. Toxigenic:			
1. <i>Cl. perfringens</i> ( <i>welchii</i> ).....			7
2. <i>Cl. novyi</i> ( <i>oedematis</i> ).....			2
3. <i>Cl. septicum</i> .....			2
4. Unidentified.....			1
B. Nontoxigenic:			
1. <i>Cl. sporogenes</i> .....			22
2. <i>Cl. putrificus</i> group.....			8
3. <i>Cl. tertium</i> .....			6
4. <i>Cl. bifementans</i> .....			1
5. <i>Cl. sphenoides</i> .....			1
6. <i>Cl. capitoralis</i> .....			1
7. Unclassified:			
a. Subterminal spores:			
(1) Proteolytic.....			2
(2) Nonproteolytic.....			1
b. Terminal spores:			
(1) Proteolytic.....			1
(2) Nonproteolytic.....			3
VI. Miscellaneous:			
A. <i>Bacteroides</i> :			
1. <i>B. melaninogenicum</i> .....			3
B. <i>Actinomyces</i> :			
1. Anaerobic.....			4
C. <i>Diphtheroids</i> :			
1. Aerobic.....			6
2. Anaerobic.....			2
D. <i>Bacillus</i> .....			3
E. <i>Bacteriaceae</i> .....			2
Total cultures.....			214



TABLE II

## OBLIGATORY ANAEROBES ISOLATED FROM WAR WOUNDS

Culture	No. of Cultures
1. <i>Clostridium</i> .....	58
2. <i>Micrococcus</i> .....	21
3. <i>Streptococcus</i> .....	9
4. <i>Actinomyces</i> .....	1
5. <i>B. melaninogenicum</i> .....	3
6. Diphtheroids.....	2
Total.....	97, or 15.3% of total

TABLE III

## MICRO-AEROPHILIC BACTERIA ISOLATED FROM WAR WOUNDS

Culture	No. of Cultures
1. <i>Micrococcus</i> .....	14
2. Undifferentiated streptococcus.....	11
3. Enteric streptococcus.....	9
Total.....	34, or 15.9% of total

TABLE IV

## AEROBES OR FACULTATIVE ANAEROBES ISOLATED FROM WAR WOUNDS

Cultures	No. of Cultures
1. Streptococcus:	
a. Beta hemolytic.....	7
b. Alpha hemolytic.....	1
c. Enteric.....	13
d. Undifferentiated.....	6
2. Staphylococcus:	
a. <i>Aureus</i> .....	14
b. <i>Albus</i> .....	3
c. Nonpigmented.....	2
3. <i>Micrococcus</i> .....	1
4. <i>Proteus</i> :	
a. <i>Vulgaris</i> .....	1
b. <i>Mirabilis</i> .....	1
5. <i>Pseudomonas aeruginosa</i> .....	4
6. <i>Aerobacter</i> .....	8
a. <i>Paracolon Aerobacter</i> .....	4
7. <i>Escherichia</i> .....	2
a. <i>Paracolon Escherichia</i> .....	2
8. Diphtheroids.....	6
9. <i>Bacillus</i> .....	3
10. <i>Bacterium</i> .....	2
11. Unidentified gram-negative bacilli.....	3
Total.....	83, or 38.8% of total

fastidious in their metabolic requirements as to preclude effective study after isolation. In all, there were 214 pure cultures of bacteria isolated from the 36 wounds (Table I) about three-fifths of which were obligatory or preferential anaerobes (Tables II and III). Only two-fifths of the cultures were aerobes or facultative anaerobes (Table IV). Listed in order of frequency, the predominant species were the *Clostridium* (58 cultures), the *nonhemolytic*

TABLE V

THE INCIDENCE OF POTENTIALLY INVASIVE OR TOXIGENIC BACTERIA—TRUE PATHOGENS

Bacteria	Cultures	
	No.	% of Total
1. Toxigenic <i>Clostridium</i> .....	12	5.6%
2. Coagulase-positive <i>Staphylococcus</i> .....	11	5.1%
3. <i>Beta hemolytic Streptococcus</i> .....	7	3.3%
Total.....	30	14.0%

TABLE VI

PROTEOLYTIC ACTIVITY OF STREPTOCOCCUS

Bacterial Cultures	Muscle	Serum	Casein	Fibrin	Gelatin	Amino-acids	
						H <sub>2</sub> S	Gas
<i>Beta hemolytic Streptococcus:</i>							
Group A—4.....	0	0	0	+	0	0	0
Group C—1.....	0	0	0	+	0	0	0
<i>Enteric Streptococcus:</i>							
21.....	0	0	0	0	0	0	0
1.....	0	+(Trace)	+	0	+	0	0
<i>Nonhemolytic Streptococcus:</i>							
Aerobic—5.....	0	0	0	0	0	0	0
Micro-aerophilic:							
4 simple.....	0	0	0	0	0	0	0
7 fastidious.....	0	0	0	0	0	0	0
Anaerobic:							
4.....	0	+	+	0	+	+	0
1.....	0	0	0	+	0	+	+
4.....	0	0	0	0	0	0	0

*Streptococci* (48 cultures) and the micrococci (36 cultures). *Clostridium sporogenes* was isolated 22 times and was the commonest single bacterial type.

The species known to be potentially invasive or toxigenic represented only 14 per cent of the total cultures isolated (Table V). Only four of the 27 grossly infected wounds presented any clinical evidence of invasive infection or specific toxemia. In three instances of gross infection none of the potential true pathogens were recovered. It seemed reasonable to conclude that the biologic emphasis in the further study of the isolated bacteria should identify the factors most likely to be concerned with the process of septic liquefaction characteristic of wound suppuration.

Although bacteriologic phraseology permits the designation of bacteria as "wound pathogens," there has been no precise definition of the cardinal attributes of such organisms. Common practice for the denomination of wound

pathogens is based upon a consideration of the essential metabolic substrate. Wound pathogens differ from true pathogens in that they are lacking in those qualities permitting a direct attack upon living tissue. Essential metabolites for growth of wound pathogens are secured in the process of septic decomposition of devitalized tissue, blood clot and wound exudate. A secondary consequence of this septic decomposition is local necrosis of living tissue exposed to the products of suppuration. Especially vulnerable in the recent wound are the relatively avascular collagenous tissues of tendon, fascia, cortical bone and cartilage. The distinction between invasive or toxigenic necrosis of living tissue and the septic decomposition of devitalized tissue has been emphasized by the introduction of chemotherapeutic agents for the control of invasive infection. There is an increasing acceptance of the capacity to digest animal protein as the distinctive attribute for identification of "wound pathogens."<sup>1, 12, 13, 14</sup>

The proteolytic capacities of the bacterial cultures were tested *in vitro* by inoculation of pure cultures into mediums containing different protein substrates. Muscle protein, serum, casein, fibrin, gelatin (modified collagen) and amino-acid mixtures were employed. The results of these tests are recorded in Tables VI, VII, VIII and IX.

The proteolytic activity of the streptococci is summarized in Table VI. The *beta hemolytic Streptococci* were typically fibrinolytic. Hyaluronidase activity was not tested because of technical difficulties and the desire to emphasize the locally necrotizing rather than the invasive attributes of the bacteria. The enterococci, with one exception, and the aerobic and *micro-aerophilic nonhemolytic Streptococci* were inert. Five of the nine cultures of *anaerobic nonhemolytic Streptococci* showed some degree of proteolysis. Thus, 41 of the 47 cultures of *nonhemolytic Streptococci* failed to qualify as proteolytic bacteria.

The staphylococcal cultures revealed a wide range of individual variation (Table VII). The coagulase test did not conform to the proteolytic tests. Of ten coagulase-positive *Staph. aureus* strains, only seven were gelatinolytic and three of nine coagulase-negative cultures were gelatinolytic. Obviously, there is need for further study to determine the relative merits of the coagulase test and gelatin liquefaction in the evaluation of wound pathogenicity for staphylococcal cultures.

Only two of the 21 cultures of anaerobic micrococci were gelatinolytic. Five cultures showed limited digestion of amino-acids. The *micro-aerophilic Micrococci* failed to grow in simple gelatin or amino-acid medium. As a group, the Micrococci appeared relatively unimportant as wound pathogens.

The four anaerobic cultures of *Actinomyces* liquefied gelatin and produced hydrogen sulfide in amino-acid medium (Table VII).

The *Clostridium* cultures are presented in order of decreasing proteolytic activity in Table VIII. *Cl. sporogenes* was the only bacterial type characterized by constant digestion of all test substrates by all cultures. This observation is made more significant by the recognition of *Cl. sporogenes*

TABLE VII

PROTEOLYTIC ACTIVITY OF STAPHYLOCOCCUS, MICROCOCCUS AND ACTINOMYCES

Bacterial Cultures	Muscle	Serum	Casein	Fibrin	Gelatin	Amino-acids		Coagulase
						H <sub>2</sub> S	Gas	
<i>Staphylococcus:</i>								
1. <i>Aureus</i> :								
2.....	0	0	0	P(weak)	+	0	0	+
1.....	0	0	0	P(weak)	+	0	0	0
1.....	0	0	0	P(weak)	0	0	0	+
2.....	0	0	0	P(weak)	0	0	0	0
5.....	0	0	0	0	+	0	0	+
2.....	0	0	0	0	0	0	0	+
1.....	0	0	0	0	0	0	0	0
2. <i>Albus</i> :								
1.....	0	0	0	0	+	0	0	0
2.....	0	0	0	0	0	0	0	0
3. Nonpigmented:								
1.....	0	0	0	0	+	0	0	0
1.....	0	0	0	0	0	0	0	0
<i>Micrococcus:</i>								
1. Microaerophilic.....								
2.....	0	0	—	0	n.g.	n.g.	n.g.	—
2. Anaerobic:								
2.....	0	0	—	0	+	+	0	—
1.....	0	0	—	0	0	+	+	—
2.....	0	0	—	0	0	+	0	—
2.....	0	0	—	0	0	0	+	—
14.....	0	0	—	0	0	0	0	—
<i>Actinomyces:</i>								
4.....	0	0	0	0	+	+	0	—

P(weak) = atypical partial dissolution of clot.  
n.g. = no growth.  
— = not tested.

TABLE VIII

PROTEOLYTIC ACTIVITY OF CLOSTRIDIUM

Bacterial Cultures	Muscle	Serum	Casein	Fibrin	Gelatin	Amino-acids	
						H <sub>2</sub> S	Gas
<i>Sporogenes</i> .....22	+	+	+	+	+	+	+
<i>Pulrificus</i> -group.....8	+ or 0	+	+	+ or 0	+	+	0
<i>Bifermentans</i> .....1	0	+	+	—	+	+	+
<i>Capitovialis</i> .....1	0	0	+	0	+	+	+
<i>Perfringens</i> .....7	0	0	0	± or 0	+	+	+
<i>Novyi</i> .....2	0	0	0	±	+	+	+
<i>Septicum</i> .....2	0	0	0	±	+	0	+
<i>Tumefaciens</i> .....1	0	0	0	±	0	+	+
<i>Tertium</i> .....6	0	0	0	0	0	+	+ or 0
<i>Sphenoides</i> .....1	0	0	0	0	0	+	0
Unidentified nontoxigenic:							
1. Subterminal spores—2	0	0	+	0	+	+	+
2. Subterminal spores—1	0	0	0	0	0	+	0
3. Terminal spores—1	0	0	0	+	+	+	0
4. Terminal spores—3	0	0	0	0	0	+	0

+ or 0 = strain inconsistencies.  
— = no test.  
± = irregular results—positive and negative reactions obtained with each of several strains.

as the most frequent single bacterial type recovered from this series of war wounds. The *Cl. putrificus* group and *Cl. bifermentans* are only slightly less active and with *Cl. sporogenes* constitute the actively proteolytic members of the *Clostridium* group. Taxonomic emphasis upon the saccharolytic properties of *Cl. perfringens*, *Cl. novyi* and *Cl. septicum* has led to disregard of their proteolytic characteristics. These potentially toxigenic *Clostridia* have a greater proteolytic activity than the staphylococci and in this series were most frequently present in their alternative rôle of wound pathogens. Among the identified *Clostridium* types only *Cl. tertium* and *Cl. sphenoides* were unable to break down any of the test proteins.

*B. melaninogenicum* grows very slowly but has well-established proteolytic ability and is recognized as an organism associated with local tissue decomposition.<sup>15</sup>

Table IX is chiefly of interest in that it confirms the slightly greater proteolytic activity of *Proteus* as compared with *Ps. aeruginosa* (pyocyanea). Among the other aerobic gram-negative bacilli only the *para-aerobacter*<sup>16</sup> cultures were regularly gelatinolytic. Only five of 21 cultures of aerobic gram-negative bacilli other than *Proteus* or *Pseudomonas* showed proteolytic activity.

Within the concept of denomination of potential wound pathogens on the basis of proteolysis observed with pure cultures, it is practical to identify certain bacterial groups as important in wound suppuration. All the true pathogens of the *Clostridium*, *Staphylococcus* and *Streptococcus* groups possess biologic activity consistent with alternative designation as simple wound pathogens. Of importance in this regard, is the recently observed enhancement of streptococcal proteolysis by serum lysate.<sup>17</sup> Other bacteria, lacking invasiveness and toxigenicity, appear at present to be important only as wound pathogens: *Clostridium* of the *sporogenes*, *putrificus* and *bifermentans* groups; aerobic gram-negative bacilli of the *Proteus*, *Pseudomonas* and *para-aerobacter* groups; certain cultures of *Staphylococcus* and *anaerobic nonhemolytic Streptococcus*; *anaerobic Actinomyces* and *B. melaninogenicum*.

Other bacteria had little or no enzymic activity for the protein substrates tested. No proteolysis was observed with the cultures of *Micrococci*, *enteric Streptococci*, *nonhemolytic Streptococci* and gram-negative bacilli of the coliform and *para-escherichia* groups. A lytic effect on amino-acids was demonstrated for *Cl. tertium*, *Cl. sphenoides* and about one-third of the cultures of *anaerobic micrococci*. For analytical purposes these bacteria have been classified as "commensal" to designate their inability to initiate proteolysis in the process of septic decomposition. Such classification does not deny these organisms an important place as synergists in the ultimate liquefaction of wound proteins. It does signify their preoccupation with simpler nitrogenous substrates appearing as intermediary catabolites in the process initiated by the enzymes of wound pathogens.

One purpose of the attempted designation of wound pathogens was to

establish a basis for a study of the penicillin sensitivities of the various bacteria important in wound suppuration. Details of the sensitivity tests are recorded in Tables X, XI and XII. A more exhaustive consideration of this phase of

TABLE IX  
PROTEOLYTIC ACTIVITY OF BACILLARY GRAM-NEGATIVE BACTERIA

Bacterial Cultures	Muscle	Serum	Casein	Fibrin	Gelatin	Amino-acids	
						H <sub>2</sub> S	Gas
<i>B. melaninogenicum</i> ..... 3	0	+	—	—	+ or 0*	—	—
<i>Proteus</i> ..... 2	0	+	+(weak)	P(weak)	+	+	0
<i>Pseudomonas</i> .... 4	0	+	+(weak)	0	+	0	0
Coliform bacilli:							
1. <i>Aerobacter</i> ..... 1	0	0	0	0	+	0	0
7	0	0	0	0	0	0	0
2. <i>Escherichia</i> ..... 2	0	0	0	0	0	0	0
Paracolon bacilli:							
1. <i>Para-aerobacter</i> .. 4	0	0	0	0	+	0	0
2. <i>Para-escherichia</i> .... 2	0	0	0	0	0	0	0
Unidentified..... 3	0	0	0	0	0	0	0

P(weak) = atypical partial dissolution of clot.

+ or 0 = strain inconsistencies.

— = not tested.

\* = taken from Prevot, A. T.—"Manual de Classification et de determination des Bacteries Anaerobies"—Monograph de L'Institute Pasteur, 1940, Masson et Cie, Paris.

TABLE X  
PENICILLIN SENSITIVITY OF STREPTOCOCCUS

Bacterial Cultures	Units/cc. Penicillin for Inhibition								Resistant Strains	Total Strains Tested
	0.025	.05	.1	.25	.5	1	2	5		
<i>Beta hemolytic Streptococcus:</i>										
Group A .....	4								0	1
Group C.....	1								0	1
<i>Enteric Streptococcus:</i>										
Gelatinolytic.....						1	4		1	1
Non-gelatinolytic..					—	—	—	—	16	21
Total.....						1	4		17	22
<i>Nonhemolytic Streptococcus:</i>										
Aerobic:										
Simple.....	1		2						0	3
Fastidious.....	1								0	1
Micro-aerophilic:										
Simple.....	1		1		1				0	3
Fastidious.....	3		2	2					1	8
Anaerobic:										
Proteolytic.....	4		1						0	5
Nonproteolytic..			1			1			0	2
Total.....	10	2	7		1	1			1	22

"H" strain of *Staph. aureus* required 0.05 units/cc. penicillin for inhibition.

the study is available elsewhere.<sup>10, 11</sup> The important implications of the observations are apparent in Table XIII. Although over 90 per cent of the cultures isolated in this series were gram-positive, not all of these were fully

sensitive to penicillin. Among the true pathogens the single completely resistant culture was a staphylococcus. Among the wound pathogens, resistant cultures included *Proteus*, *Pseudomonas*, *para-aerobacter*, several cultures of

TABLE XI  
PENICILLIN SENSITIVITY OF STAPHYLOCOCCUS, MICROCOCCUS AND ACTINOMYCES

Bacterial Cultures	Units/cc. Penicillin for Inhibition								Resident Strains	Total Strains Tested
	.025	.05	.1	.25	.5	1	2	5		
<i>Staphylococcus aureus</i> :										
Coagulase—positive:										
Gelatinolytic.....		3	2						1	6
Nongelatinolytic.....		1	3						0	4
Coagulase—negative:										
Gelatinolytic.....									1	1
Nongelatinolytic.....			1			1			0	2
<i>Albus</i> .....		3							0	3
Nonpigmented.....		2							0	2
Total.....		9	6			1			2	18
<i>Micrococcus</i> :										
Micro-aerophilic.....	4	6	1	1	2				0	14
Anaerobic:										
Proteolytic.....	2					1			0	3
Nonproteolytic.....	11					1	1		0	13
Total.....	17	6	1	1	2	2	1		0	30
<i>Actinomyces</i> .....	3								0	3

"H" strain of *Staph. aureus* required 0.05 units/cc. penicillin for inhibition.

TABLE XII  
PENICILLIN SENSITIVITY OF CLOSTRIDIUM

Bacterial Cultures	Units/cc. Penicillin for Inhibition								Resistant Strains	Total Strains Tested
	.025	.05	.1	.25	.5	1	2	5		
<i>Novyi</i> .....	2								0	2
<i>Seplicum</i> .....	2								0	2
<i>Putrificus</i> group.....	7	1							0	8
<i>Tumefaciens</i> .....		1							0	1
<i>Bifermentans</i> .....			1						0	1
<i>Capitovolis</i> .....				1					0	1
<i>Perifringens</i> .....				4	3				0	7
<i>Sporogenes</i> .....				2	8	8	4		0	22
<i>Tertium</i> .....						1	2		0	3
<i>Sphenoides</i> .....									1	1
Unidentified:										
Subterminal spores.....					3				0	3
Terminal spores.....		4							0	4
Total.....	11	6	1	7	14	9	6		1	55

"H" strain of *Staph. aureus* required 0.05 units/cc. penicillin for inhibition.

*Cl. sporogenes*, a few cultures of the staphylococci and, by inference, *B. melaninogenicum*. These bacteria emerge as the groups resistant to presently available chemotherapeutic agents in wound suppuration. Other bacteria, in-

cluding many penicillin-resistant types, were in the group established as commensal.

TABLE XIII  
CORRELATION OF PATHOGENICITY AND PENICILLIN SENSITIVITY

Culture	True Pathogen	Wound Pathogen	Commensal	Penicillin Sensitivity*
<i>Staphylococcus</i> .....	+	+	+	0.05—Resistant
<i>Hemolytic Streptococcus</i> .....	+	+	0	0.025
<i>Clostridium</i> :				
1. <i>Novyi</i> .....	+	+	0	0.025
2. <i>Septicum</i> ....	+	+	0	0.025
3. <i>Perfringens</i> .....	+	+	0	0.25—0.5
4. <i>Putrificus</i> .....	0	+	0	0.025—0.05
5. <i>Bifermentans</i> .....	0	+	0	0.1
6. <i>Sporogenes</i> .....	0	+	0	0.25—2.0
7. <i>Tertium</i> .....	0	0	+	1.0—2.0
8. <i>Sphenoides</i> ..	0	0	+	Resistant
<i>Streptococcus</i> :				
1. Anaerobic proteolytic.....	0	+	0	0.025
2. Other anaerobic.....	0	0	+	0.1—2.0
3. Nonhemolytic.....	0	0	+	0.25—Resistant
4. Enteric.....	0	0	+	1.0—Resistant
<i>Micrococcus</i> .....	0	0	+	0.025—2.0
<i>Actinomyces</i> .....	0	+	0	0.025

\*Sensitivity expressed in units/ml. required for inhibition of growth.

TABLE XIV  
INFECTED WAR WOUNDS OF THE UPPER EXTREMITY

No.	Age of Wound	Injury	Clinical Diagnosis of Infection	Bacteria Isolated from War Wounds		
				True Pathogens	Wound Pathogens	Commensals
1.	33 days	S. P.	Acute cellulitis	<i>Hem. Strept.</i> (gr. A) <i>Staph. aureus</i>		<i>Nonhem. Strept.</i>
2.	9 days	C. F.	Gangrenous erysipelas	<i>Hem. Strept.</i> (gr. ?)	<i>Pseudomonas Aerobacter</i>	<i>Enteric Strept.</i>
3.	17 days	C. F.	Wound suppuration	<i>Cl. perfringens</i> <i>Staph. aureus</i>	<i>Cl. bifermentans</i> <i>Micrococcus</i> (anaer.) <i>Clostridium</i> (unident.)	<i>Cl. sphenoides</i> <i>Clostridium</i> (unident.) <i>Enteric Strept.</i> <i>Micrococcus</i> (anaer.) <i>Micrococcus</i> (micro-aer.) <i>Diphtheroid</i> (anaer.)
4.	12 days	S. P.	Wound suppuration	<i>Staph. aureus</i>	<i>Cl. sporogenes</i>	<i>Nonhem. Strept.</i>
5.	10 days	S. P.	Wound suppuration	<i>Staph. aureus</i>	<i>Cl. sporogenes</i> <i>Actinomyces</i> <i>Nonhem. Strept.</i> (anaer.)	<i>Nonhem. Strept.</i> <i>Nonhem. Strept.</i> (micro-aer.) <i>Diphtheroid</i>

In this and subsequent tables:

- S. P. =soft-parts.
- C. F. =compound fracture.
- Unident. =unidentified.
- Anaer. =anaerobic.
- Micro-aer. =micro-aerophilic.

These observations establish the fact that there are several wound pathogens commonly present in wounds and resistant to chemotherapy. This is in addition to the clinical evidence that no available therapy can prevent the



septic decomposition of devitalized tissue in an open wound. On this basis it is argued that presently available chemotherapy can affect the problem of wound sepsis only through control of the invasive component of the infection. Other methods are mandatory for the control of local suppuration.

It may be stated that *the nutritional pabulum of wound protein is of far greater clinical importance than the taxonomic classification of the bacterial contaminants concerned with its septic decomposition.* The protein of devital-

TABLE XV  
INFECTED WAR WOUNDS OF THE LOWER LEG

No.	Age of Wound	Injury	Clinical Diagnosis of Infection	Bacteria Isolated from War Wounds		
				True Pathogens	Wound Pathogens	Commensals
6.	25 days	C. F.	Erysipelas and acute cellulitis	<i>Hem. Strept.</i> (gr. A)		<i>Aerobacter</i> <i>Micrococcus</i> <i>Micrococcus</i> (anaer.) <i>Diphtheroid</i> (anaer.)
7.	19 days	C. F.	Wound suppuration	<i>Staph. aureus</i>		<i>Aerobacter</i> Enteric <i>Strept.</i> <i>Nonhem. Strept.</i> <i>Micrococcus</i> (anaer.) <i>Micrococcus</i> (micro-aer.) Diphtheroid
8.	25 days	C. F.	Wound suppuration	<i>Staph. aureus</i>	<i>B. melanogenicum</i> <i>Nonhem. Strept.</i> (anaer.)	<i>Micrococcus</i> <i>Micrococcus</i> (micro-aer.) <i>Micrococcus</i> (anaer.)
9.	24 days	C. F.	Wound suppuration	<i>Staph. aureus</i>	<i>Cl. sporogenes</i> <i>Para-aerobacter</i> <i>Actinomyces</i> <i>B. melanogenicum</i>	<i>Cl. tertium</i> Enteric <i>Strept.</i> <i>Nonhem. Strept.</i> (2) <i>Nonhem. Strept.</i> (anaer.) <i>Micrococcus</i> (anaer.)
10.	22 days	C. F.	Wound suppuration	<i>Cl. novyi</i> <i>Cl. perfringens</i> <i>Staph. aureus</i>	<i>Cl. sporogenes</i>	<i>Cl. tertium</i> <i>Aerobacter</i> <i>Para-escherichia</i> <i>Nonhem. Strept.</i> Enteric <i>Strept.</i>
11.	29 days	C. F.	Wound suppuration		<i>Cl. sporogenes</i> <i>Cl. putrificus</i> group <i>Para-aerobacter</i>	<i>Nonhem. Strept.</i> (micro-aer.) <i>Bacillus</i> Diphtheroid
12.	28 days	C. F.	Wound suppuration	<i>Hem. Strept.</i> (gr. C)	<i>Cl. sporogenes</i> <i>Cl. putrificus</i> group <i>B. melanogenicum</i> <i>Nonhem. Strept.</i> (anaer.)	<i>Cl. tertium</i> <i>Micrococcus</i> (anaer.)

ized tissue affords an acceptable substrate for growth of anaerobic wound pathogens. Wound exudate protein affords a nutritional pabulum for growth of aerobic wound pathogens. Lister gave especial emphasis to excision of devitalized tissue as the means of controlling anaerobic infection.<sup>18, 19, 20</sup> Also well-recognized in listerian philosophy was the fact that *the control of wound exudation is as important as the excision of dead tissue in the surgical management of contaminated or infected wounds.*

## CLINICAL CONSIDERATIONS

Tables XIV, XV, XVI, and XVII correlate the important clinical and bacteriologic features of 26 grossly infected wounds. *Beta hemolytic Streptococci* were recovered from seven wounds (Nos. 1, 2, 6, 12, 14, 17, 18), but in only three wounds (Nos. 1, 2, 6) was there clinical evidence of the invasive or toxigenic pattern of streptococcal infection. Toxigenic *Clostridium* were present in seven wounds (Nos. 3, 10, 15, 16, 17, 19, 23) but in only one patient (No. 16) was there clinical evidence of toxemia. In three wounds (Nos. 11, 22, 26) there were no demonstrable true pathogens. In three wounds (Nos. 1, 6, 7) there were no demonstrable wound pathogens. In 19 wounds (Nos. 2-5, 8-12, 16-26) there were wound pathogens known to be relatively or completely resistant to penicillin. All these infections developed in spite of sulfonamide therapy. The high incidence of *Cl. sporogenes*, particularly in septic arthritis, is noteworthy.

In the management of these wounds, dead tissue and sequestra were removed surgically under the protection of systemic penicillin therapy. The wounds *were left open and dressed with pressure and splints* to control wound exudation. It had already been learned that primary closure of excised infected wounds ran the risk of anaerobic cellulitis.<sup>1</sup> The clean surgical appearance of the wound three to ten days later was used as the criterion of absence of infection. The first subsequent dressing of the wounds was done in the operating room with adequate facilities to perform secondary operations. "Clean" wounds were closed immediately by secondary suture or skin grafting. "Dirty" wounds were subjected to further excision of tissue devitalized by previous excision or by subsequent infection. Systemic penicillin was used throughout the period of treatment until the danger of impending or established invasive infection was past. No local chemotherapy was used. The successful management of these wounds, without endangering life or limb, has been recorded in detail.<sup>10</sup>

Table XIII summarizes the essential bacteriologic and clinical data on ten patients injured by high explosive shell fragments. All received systemic sulfonamide therapy after initial surgical treatment. The original postoperative dressings were changed for the first time in the operating room of the Base Section Hospital. Clinical appearance of the wound dictated further excision of dead tissue or a reparative surgical procedure.

Cases 27, 28, 29 and 30 were *clean* soft-part wounds. They were closed by secondary suture or skin grafting *at the time* of the first change of dressing. No chemotherapy was given, and the wounds healed without infection. Wound cultures were obtained from the entire blood clot and swabs of the wound. No invasive or toxigenic bacteria or wound pathogens were recovered. The only organisms present were of the commensal group. All these strains were shown by test to have no proteolytic activity. *This is bacteriologic proof that the gross surgical pathologic condition of a soft-parts wound gives more information than the routine bacteriologic study of that wound.* Many thousands of similar soft-parts wounds have been closed or grafted on this basis.<sup>7, 21</sup> It

appears that 5 to 10 per cent of these wounds subsequently show some local inflammatory reaction but there has been no reported instance of serious infection.

Case 31 typifies a *dirty* soft-parts wound with no evidence of invasive infection. Anaerobic infection of residual dead tissue was recognized. Clinically, it was impossible to tell whether this was infection with wound pathogens or with potentially invasive *Clostridia* acting as wound pathogens. Sec-

TABLE XVI  
INFECTED WAR WOUND OF THE THIGH

No.	Age of Wound	Injury	Clinical Diagnosis of Infection	Bacteria Isolated from War Wounds		
				True Pathogens	Wound Pathogens	Commensals
13.	26 days	C. F.	Wound suppuration	<i>Staph. aureus</i>	<i>Nonhem. Strept.</i> (anaer.)	<i>Nonhem. Strept.</i> (anaer.) <i>Micrococcus</i> (micro-aer.)
14.	45 days	C. F.	Wound suppuration	<i>Hem. Strept.</i> (gr. A)	<i>Cl. putrificus</i> group	<i>Micrococcus</i> (micro-aer.) Diphtheroid
15.	45 days	C. F.	Wound suppuration	<i>Cl. perfringens</i>	<i>Cl. putrificus</i> group	<i>Staph. albus</i> Enteric <i>Strept.</i> <i>Micrococcus</i> (micro-aer.)
16.	5 days	C. F.	<i>Clostridial</i> myositis	<i>Cl. perfringens</i>	<i>Cl. sporogenes</i> <i>Pseudomonas</i>	<i>Escherichia</i> <i>Micrococcus</i> (anaer.) 2 <i>Micrococcus</i> (micro-aer.) Enteric <i>Strept.</i>
17.	7 days	C. F.	Wound suppuration	<i>Cl. perfringens</i> <i>Staph. aureus</i> <i>Hem. Strept.</i> (gr. A)	<i>Cl. sporogenes</i> <i>Clostridium</i> (unident.) <i>Paraaerobacter</i>	<i>Clostridium</i> (unident.) <i>Micrococcus</i> (anaer.) <i>Nonhem. Strept.</i> (micro-aer.)
18.	41 days	C. F.	Wound suppuration	<i>Hem. Strept.</i> (gr. ?)	<i>Cl. sporogenes</i> <i>Cl. putrificus</i> group	<i>Clostridium</i> (unident.) <i>Escherichia</i> Enteric <i>Strept.</i> <i>Nonhem. Strept.</i> (micro-aer.) <i>Micrococcus</i> (anaer.)
19.	17 days	C. F.	Wound suppuration	<i>Cl. novyi</i>	<i>Cl. sporogenes</i> <i>Actinomyces</i>	<i>Cl. tertium</i> <i>Aerobacter</i> Enteric <i>Strept.</i> <i>Micrococcus</i> (anaer.) <i>Micrococcus</i> (micro-aer.) Diphtheroid Gram-neg. bacillus (unident.)
20.	27 days	C. F.	Wound suppuration	<i>Staph. aureus</i>	<i>Cl. sporogenes</i> <i>Cl. capitovialis</i> (?) <i>Actinomyces</i>	<i>Staph. albus</i> <i>Parascherichia</i> <i>Nonhem. Strept.</i> Enteric <i>Strept.</i> <i>Nonhem. Strept.</i> (anaer.) 2 <i>Micrococcus</i> 2 <i>Micrococcus</i> (anaer.) 2

ondary wound excision was performed, penicillin was given and the wound closed by secondary suture five days later. Cultures of the wound demonstrated only proteolytic anaerobes and commensal bacteria.

Cases 32, 33 and 34 were *clean* wounds in association with compound comminuted fractures. Complete débridement of a fracture cannot be performed without needless sacrifice of bone. Nor does devitalized bone in a wound convey the same hazard of life endangering infection as devitalized muscle. Clinical experience has recognized the constant contamination of a compound fracture site after a lapse of more than six hours. Cultural studies of the

blood clot from the fracture site in these otherwise clean wounds revealed toxigenic and proteolytic *Clostridium* types. Clinical appraisal must take this probable contamination of the compound fracture into consideration. Penicillin has been recommended at the time of débridement for all compound fractures. It is considered mandatory for all secondary operations upon wounds complicated by fracture. Secondary closure of wounds over compound fractures is *not necessarily skin closure*. The technical objectives are obliteration of dead space and the covering of exposed cortical bone with vascular soft parts. Simple skin wounds will usually epithelize long before the fracture has healed. Bone defects or severe comminution contradict complete closure of all wounds. Dependent drainage of the fracture site must be established in anticipation of the ultimate septic decomposition of a contaminated hematoma.

Cases 35 and 36 are instances of dry gangrene after arterial injury. The cultures were biopsies of dead muscles taken at a considerable distance from the site of compound injury. Actively proteolytic bacteria were recovered in both cultures. The association of dead tissue and proteolytic bacteria is so constant as to suggest it as an inevitable consequence of incomplete débridement.

The bacteriologic picture and the clinical problem presented by the clean soft-parts wound must be distinguished from that common to the suppurative soft-parts wound and the wound complicated by fracture. Potentially invasive or toxigenic anaerobes have been demonstrated in both these latter types of wounds. The absence of clinical signs of invasiveness or toxemia cannot exclude the presence of true pathogens existing in the wound in their alternative rôle as proteolytic bacteria. Two cases of fatal gas gangrene are known to have followed secondary operations upon compound fractures without protective penicillin therapy. The superiority of penicillin over sulfonamide for these infections has been generally acknowledged.<sup>22, 23</sup> No fatalities have been recorded from infection as a consequence of secondary operations, including internal fixation, for several hundred compound fractures receiving penicillin. The soft-parts wounds with deep recesses, suppurative soft-parts wounds and compound fractures merit penicillin therapy as an adjunct to primary and secondary surgical management on the basis of an established risk of toxigenic *Clostridium* infection. The important technical considerations in the reparative management of compound fractures have been reviewed by Hampton.<sup>24</sup>

The major risk of invasive infection in the cleanly excised soft-parts wound is from the *beta hemolytic Streptococcus*. It is impossible to assess the therapeutic value of routine sulfonamide therapy after initial surgery in this group of cases. Of greatest importance to this program of secondary suture without further chemotherapy is the absence of any delay between removal of the first dressing and closure of the wound. The gross surgical pathologic picture of the soft-parts wound is a reliable index of infection only after the lapse of three to five days from the time of the last dressing. Chemo-

TABLE XVII

## SEPTIC ARTHRITIS AS A COMPLICATION OF WAR WOUNDS

No.	Age of Wound	Injury	Clinical Diagnosis of Infection	Bacteria Isolated from War Wounds		
				True Pathogens	Wound Pathogens	Commensals
21.	20 days	Wrist	Septic arthritis	<i>Staph. aureus</i>	<i>Cl. sporogenes</i>	<i>Aerobacter</i> <i>Enteric Strept.</i>
22.	20 days	Elbow	Septic arthritis		<i>Cl. sporogenes</i> <i>Cl. putrificus</i> group <i>Proteus mirabilis</i>	<i>Enteric Strept.</i>
23.	25 days	Knee	Septic arthritis	<i>Cl. tumefaciens(?)</i>	<i>Cl. sporogenes</i> <i>Paraerobacter</i>	<i>Enteric Strept.</i> Diphtheroid
24.	23 days	Knee	Septic arthritis	<i>Staph. aureus</i>	<i>Cl. sporogenes</i>	<i>Micrococcus</i> (micro-aer.) Gram-neg. bacillus (unident.)
25.	27 days	Knee	Septic arthritis	<i>Staph. aureus</i>	<i>Cl. sporogenes</i>	<i>Enteric Strept.</i> <i>Micrococcus</i> (anaer.) <i>Micrococcus</i> (micro-aer.)
26.	24 days	Knee	Septic arthritis		<i>Cl. sporogenes</i> <i>Cl. putrificus</i> group <i>Pseudomonas</i>	<i>Enteric Strept.</i> <i>Clostridium</i> (unident.) <i>Micrococcus</i> (anaer.)

TABLE XVIII

## BACTERIOLOGY OF WAR WOUNDS WITHOUT GROSS INFECTION—ALL WOUNDS HEALED WITHOUT INFECTION UNDER TREATMENT AS INDICATED

No.	Age of Wound	Injury and Appearance	Bacteria Recovered from Wound			Treatment	Chemo-therapy
			True Pathogens	Wound Pathogens	Commensal		
27.	6 days	S. P., clean			<i>Enteric Strept.</i> <i>Bacillus</i>	Skin graft	0
28.	6 days	S. P., clean			<i>Enteric Strept.</i> <i>Micrococcus</i> (anaer.)	Sec. closure	0
29.	3 days	S. P., clean			<i>Nonhem. Strept. 2</i> <i>Staph. (non-pig.)</i>	Sec. closure	0
30.	3 days	S. P., clean			<i>Cl. tertium</i> <i>Enteric Strept.</i> <i>Micrococcus</i> (anaer.)	Sec. closure	0
31.	7 days	S. P., dirty		<i>Cl. sporogenes</i> <i>Cl. putrificus</i> group	<i>Enteric Strept.</i> <i>Nonhem. Strept. (anaer.)</i> <i>Micrococcus</i> (anaer.) <i>Micrococcus</i> (micro-aer.)	Excision and Sec. closure	Pen.
32.	2 days	C. F., clean	<i>Cl. septicum</i>	<i>Cl. sporogenes</i> <i>Micrococcus</i> (anaer.)	<i>Enteric Strept.</i> <i>Bacillus</i> <i>Bacterium</i>	Sec. closure	Pen.
33.	7 days	C. F., clean	<i>Cl. perfringens</i> <i>Cl. septicum</i>	<i>Cl. sporogenes</i>	<i>Enteric Strept.</i> <i>alpha hem. Strept.</i> <i>Staph. albus</i> <i>Bacterium</i>	Int. fixation and sec. closure	Pen.
34.	10 days	C. F., clean	<i>Cl. perfringens</i>	<i>Cl. sporogenes</i> <i>Clostridium</i> (unident.) <i>Pseudomonas</i> <i>Paraerobacter</i> <i>Cl. sporogenes</i>	<i>Cl. tertium</i> <i>Nonhem. Strept. 2</i>  Gram-negative bacillus (unident.) <i>Nonhem. Strept.</i> <i>Aerobacter</i>	Sec. closure	Pen.
35.	12 days	Dry gangrene (muscle culture)				Amputation	0
36.	6 days	Dry gangrene (muscle culture)		<i>Pr. vulgaris</i>	<i>Staph. (nonpig.)</i>	Amputation	0

therapy should complement secondary suture of the wound contaminated by a recent dressing.

Local penicillin therapy was used occasionally, but only as a supplement to systemic administration in the treatment of injuries or infections involving the joints, serous cavities or subarachnoid space since with systemic administration it does not readily penetrate these cavities. No local therapy was used in other wounds, reliance being placed on systemic penicillin to check or abolish invasive infection. The fundamental surgical philosophy of reparative wound management assigns priority to the technical surgical care of the wound.

In the years before there was a plentiful supply of penicillin, Florey and Cairns<sup>5</sup> were privileged to make an extensive investigation of local penicillin therapy. It is interesting that the local use of chemotherapy necessitated the

TABLE XIX

CLINICAL IMPLICATIONS OF A SURGICAL PHILOSOPHY ACCEPTING OR REJECTING LOCAL APPLICATION OF A CHEMOTHERAPEUTIC AGENT

Local Chemotherapy	Systemic Chemotherapy
1. Assigns priority to sterilization of wound	1. Assigns priority to surgical preparation of the wound
2. Assumes a wound can be sterilized of all pathogens	2. Asserts that no available antibacterial agent removes all pathogens from a wound
3. Regards "gram-negative pus" as an acceptable component of wound healing	3. Regards "gram-negative pus" as evidence of locally necrotizing infection with aerobic wound pathogens
4. Endorses "wound trimming" as a substitute for complete débridement	4. Permits of no compromise with substitutes for the complete excision of devitalized tissue
5. Clinical management is dictated by bacteriologic findings	5. Clinical management is dictated by gross pathology of wound
6. Recommends repeated dressings or irrigations of the wound	6. Demands an undisturbed and occlusive pressure dressing and splinting
7. Recognizes clinical failures as "drug failures"	7. Recognizes clinical failures as errors in surgical judgment or technic.

evolution of a philosophy of wound management differing in several important details from the philosophy of reparative wound management (Table XIX). It was the considered opinion of the British investigators that "if large quantities of penicillin were freely available, there can be no question that parenteral administration should in nearly all cases be practiced."

DISCUSSION.—The initial surgical management of a war wound is the most important single factor in determining ultimate salvage of the battle casualty. Dead or devitalized tissue must be excised without surgical insult and the war wound must be left open.<sup>25, 26</sup> Absence of fixed forward hospitals in World War II made it impractical to attempt primary suture as practiced by Le Maitre<sup>27</sup> and Pool<sup>28</sup> within the forward area in World War I.

There are no simple rules for subsequent management of the open wound after débridement. The problem is frequently complicated by the presence of residual dead tissue and blood clot, especially in compound fractures. In earlier surgical experience the hazard of invasive infection dictated primary consideration of the identity of the bacteria in war wounds. The bacteriologic

picture was confused by the wide variety of organisms concerned in the septic decomposition of dead tissue protein. An altered perspective followed the introduction of antibacterial agents for the control of invasive infection. The major problem in wound management became the control of local suppuration.

It is believed the bacteriologic and clinical evidence presented in this report again establishes the nutritional pabulum of dead tissue and wound exudate protein as more important than the identity of the bacteria concerned with its liquefaction. Dead tissue protein and hematoma sustain anaerobic and aerobic bacteria. Wound exudate protein is most available to aerobic bacteria. The gross surgical pathologic condition of the open wound is more directly and accurately informative than any reasonable bacteriologic analysis. It is pertinent to review older methods of wound management from this vantage point.

The Carrel-Dakin's regimen provided for the *chemical digestion of residual dead tissue protein*.<sup>29</sup> It failed to provide protection against invasive hemolytic streptococcal infection. This risk was increased by the necessity for frequent dressings. An elaborate dressing routine was designed to prevent contamination from the noses and throats of the surgical attendants. The presence of *hemolytic Streptococci* in the wounds became the chief clinical concern of the surgeon. Bacteriologists were given a full-time task in the counting and culturing of streptococci in wound exudates. In spite of all these precautions it was demonstrated in World War I that streptococcal contamination was present in many of the wounds during the period of hospitalization.<sup>30</sup> Under these circumstances secondary surgical procedures proved hazardous.<sup>28</sup> The method was so painful, elaborate and time-consuming that it was gradually abandoned as routine treatment for open wounds following compound injuries in civilian life.

The closed plaster methods of Pirogoff, Orr and Trueta provided for the *bacterial digestion of dead tissue protein*. Invasive bacterial infection was reduced to a minimum by infrequent changes of dressings and prolonged splinting. The locally necrotizing action of retained products of suppuration was minimized by dependent drainage and the use of plaster to absorb wound exudates. This method accepts the ultimate sequestration of incompletely detached and exposed bone fragments and permits no direct attempts to revascularize such fragments. The prolonged suppuration makes some degree of wound cachexia inevitable. The resultant weight loss and muscular atrophy make it difficult and often impossible to maintain bone alignment with infrequent plaster changes in many instances. The closed plaster method pays a price in fracture deformity and the proteolytic digestion of collagenous tissue structures. It is still the method of choice in the management of overwhelming numbers of casualties. It retains a clinical usefulness for the management of incompletely sequestered bone fragments provided vulnerable soft-parts are protected from the wound exudate by a surface of granulation tissue or epithelium. Its relative advantage in the control of invasive infection has been superseded by available antibacterial agents.

The reparative method of wound management provides for the *surgical*

*excision of dead tissue protein and a closed wound.*<sup>26</sup> It also permits an attempt to revascularize partly detached bone fragments by apposition of soft-parts over exposed bone. Invasive infection is controlled by the *systemic* use of chemotherapeutic agents. Anaerobic wound infection is controlled by the excision of dead tissue protein and the avoidance of primary wound closure. Aerobic wound infection is controlled by preventing wound exudation through the use of splints, pressure dressings and secondary closure of clean wounds. Contamination of wounds with air-borne wound pathogens is decreased by the abandonment of needless changes of dressing. Repeated local applications of antibacterial agents are incompatible with the efforts to prevent wound exudation and the accumulation of exudate protein in the wound. The reparative program of wound management extends the scope of surgery to the more effective correction of deformity, lessens the hazard of invasive and chronic sepsis and accelerates rehabilitation of the patient.<sup>7</sup>

The rôle of chemotherapy in wound management in the Mediterranean Theater was as an adjuvant to a surgical program of reparative wound management. No antibacterial agent was used for the prophylaxis of infection. The drugs were used therapeutically to control impending or established invasive infection. Wound suppuration was not controlled by chemotherapy alone. The topical use of antibacterial agents was contradicted by the philosophy of reparative wound management.

Lest it escape the casual reader, these investigations have affirmed the soundness of the listerian principle of treating the local wound by surgical measures. The recent advances in wound management, if they be so adjudged, are attributable to the improved protection of the individual from the systemic consequence of local wounding.

#### CONCLUSIONS

1. *Lister's Axiom*: "The essential cause of suppuration in wounds is decomposition brought about by the influence of the atmosphere upon blood or serum retained within them, and in the case of contused wounds, upon portions of tissue destroyed by the violence of the injury."

*Corollary*: The presence of a pabulum of wound protein nutritionally acceptable to wound pathogens is of far greater clinical importance than the identity of the bacterial contaminants concerned with its septic decomposition.

2. *Lister's Axiom*: "The pernicious influence of decomposing animal matter upon the tissues has probably been underrated. . . . Before a raw surface has been granulated, an acrid discharge acts with unrestrained effect upon it . . . producing by its caustic action a greater or less extent of slough."

*Corollary*: Wound suppuration is an intolerable complication of sound management, especially in the recent wound.

3. *Lister's Axiom*: "Putrescent serum would produce inflammatory disturbance."

*Corollary*: The control of wound exudation is as important as the excision of devitalized tissue in the prevention of wound suppuration.



4. *Lister's Axiom*: "Supposing an antiseptic . . . to be employed, . . . the wound would be more or less irritated by it, and in proportion to this irritation would effusion be increased . . . ; and if, in spite of the antiseptic means, active septic matter had been introduced, putrefaction . . . would be the natural result."

*Corollary*: "Experience in wound management justifies the abandonment of local use of any chemical agent in a wound for its supposed antiseptic effect in the prevention or treatment of infection." War Department Circular Letter No. 160, par. V, 1, dated June 1, 1945.

5. *Lister's Axiom*: "The suppression of the septic element enlarges the capabilities of surgery in the constitutional direction no less than in the local."

*Corollary*: Specific chemotherapy, given by the systemic route, is a proper adjuvant to an expanded surgical program for more effective wound management.

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DISCUSSION.—DR. J. ALBERT KEY, St. Louis, Mo.: I have not understood why the Army threw the local sulfonamides out the window before they had anything adequate to put in their place. I concede that penicillin is a more potent agent than the sulfonamides, and admit that neither will sterilize a wound full of dead tissue or foreign bodies. But there is not the slightest doubt in my mind that pathogenic bacteria do not grow as well in a medium saturated with sulfanilamide or sulfathiazole, or which contains an adequate concentration of penicillin, as in the same medium in which those agents are absent.

We know there are limitations to the use of local chemotherapy. It must be combined with competent surgery, as competent as you can get. If I had a compound wound and was not going to get to a surgeon for 12 hours, I would like to have somebody throw a handful of sulfanilamide in that wound and put a dry pressure dressing on it. I have not seen military surgery at the front in this war, but I have seen civilian wounds, and the results are good when treated with local and general chemotherapy. A lot of benefit has been due to chemotherapy and some to more radical surgery. I believe that with adequate local and systemic chemotherapy radical excision can be modified. If

you tell the average surgeon he has to do complete excision of every wound he will do a block excision and may do more harm than good. We must save as much tissue as possible.

I still use local sulfonamides but I have stopped using powder. I wash the wound out with a saturated solution of sulfanilamide or sulfathiazole, or of both, and I have never had such nice healing of wounds. When I review my clinical experience with local chemotherapy during the past six years, all the bacteriologic evidence that could be piled on this table would not make me change my mind. But it must be used intelligently.

DR. ROY D. McCURE, Detroit, Mich.: I was on the subcommittee of Infected Wounds and Burns of the National Research Council, and I remember Doctor Key's criticism of that Committee and Meleney's report to the American Surgical Association. I know of no member of the Committee who has changed his mind as to the conclusion reached that the use of the sulfa drugs in wounds is far from the ideal treatment. This conclusion was reached after careful study of results reported by a sufficient number of clinic projects with a large number of cases so treated and similar numbers of control cases where the sulfa drugs were not used locally.

Those of us who were in the last war realize what an advance has been made in this war in the opportunities for research in the Army itself. Doctor Lyons was on the Subcommittee of the National Research Council. When he was taken into the Army and assigned to Halloran Hospital there was opportunity in the splendid laboratory for research studies on penicillin, and this work was beautifully executed. Our eyes were opened to the opportunity that should always be present in the Army and Navy for the adequate study of new drugs and technics. We congratulate Surgeon General Kirk for making this possible. It was not possible in the last war, to the best of my knowledge.

COL. GEORGE G. FINNEY, Baltimore, Maryland: I do not want to further this argument, but I do want to put forward some facts I had a chance to observe during the Okinawa campaign. Before going into this campaign, it was felt that the incidence of *Clostridium* infections might be considerably increased. The reason for this was the extensive use of night soil for fertilizer as the war moved east and, therefore, the incidence of gas gangrene might be greater than it had been up to that time. The facts were, so far as we can tell from examining the records of nearly 20,000 battle casualties taken care of in Field Hospitals during that campaign, that there were only 48 definite clinical *Clostridium* infections. I emphasize clinical because I think this is the only proper way to make a diagnosis since the organism can often be grown from wounds where there is no clinical evidence of gas gangrene. I am not even sure that all 48 were true *Clostridium* infections.

Because of the volume of cases and, for a considerable part of the campaign, an inadequate number of surgeons, all the wounded did not receive surgery as early as we would have liked. In fact, some of the less serious cases went as long as two or three days before adequate débridement was done. The one type of therapy all battle casualties received immediately was systemic penicillin. We did not use, except sporadically, local chemotherapy in wounds. I am simply offering this for what it is worth, but it does make one wonder whether or not systemic penicillin did not have some definite beneficial effect. It must be emphasized, however, that there is no substitute for proper surgery.

DR. CHAMP LYONS, New Orleans, La. (closing): I would like to emphasize just one statement. Doctor Key brought out that he thought through the use of local chemotherapy it was possible to compromise with excision of devitalized tissue. I think the total military experience condemns any attempt at wound treatment short of removal of all devitalized tissue.

## THE PREVENTION AND TREATMENT OF POSTOPERATIVE LYMPHEDEMA OF THE ARM\*

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POSTOPERATIVE LYMPHEDEMA of the arm has occurred ever since Halsted and Willy Meyer advocated the radical mastectomy—removing the pectoral muscles and the axillary contents. Fortunately, this distressing condition is not common but it is surprising that so little thought has been given to its prevention and treatment. In fact, it has been possible to find but 13 published articles in the British and American literature dealing specifically with this subject.

While it is not within the scope of this paper to discuss any other aspects than the prevention and treatment of postoperative swelling of the upper limb, in the absence of demonstrable recurrence, it would seem appropriate to summarize briefly some of the current trends concerning the cause of such swelling.

Halsted was the first to call the attention of the medical profession to this puzzling condition. His classic article, published in 1921, has shed a great deal of light on the subject. He was of the opinion "that although blocking of the lymphatics and occasionally also of the veins was the underlying factor, infection played a conspicuous part in the determination of the amount of swelling and the time of its manifestation." The infection, he said, "may be so mild in degree as to escape observation even of those constantly on the lookout for it." Reichert and Bidgood provided experimental support of Halsted's theory. They showed that, after complete division and suture of all the tissues of the hind legs of dogs, except the femur, the femoral vessels and nerve trunks, lymphedema failed to occur and new lymphatics could be shown to cross the line of suture by the fourth day and that, by the eighth day "the regeneration was physiologically adequate." That the Reichert and Bidgood experiment and radical mastectomy are two comparable procedures is very hard to sustain. A clean circular cut across the limb was made and resutured, while in radical mastectomy, as it has been pointed out by Devenish and Jessop, not only is the whole mass of regional lymph nodes removed but also varying lengths of the main lymphatics of the arm.

Veal, believing that the obstruction on the axillary vein is a more important factor in the production of lymphedema than Halsted had shown, classified lymphedema into: lymphatic obstruction; axillary vein occlusion or constriction; and combined lymphatic and venous obstruction. Some of Veal's main statements concerning the nature and pathogenesis of the condition have been strongly challenged by Devenish and Jessop. In the most enlightening articles since Halsted's contribution, they have clarified much of the uncertainty that formerly existed about this subject.

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\* Read before the Fifty-seventh Annual Session of the Southern Surgical Association, December 4-6, 1945, Hot Springs, Virginia.

According to these writers "lymphatic obstruction alone is sufficient to cause the postoperative nonmalignant swelling, and the rise of venous pressure, as occurs during exercise (Hooker, 1911), can be a contributing factor in edema formation only in the presence of lymphatic obstruction. To explain the fact that not all the patients, subjected to a nearly identical operation, develop swelling of the arm they suggest the following theory: "The lymphatics in the subcutaneous tissues are chiefly large draining trunks with very few of the smaller vessels and very few capillary lymphatics. They do not lie directly on, and rarely in, the deep fascia (Gray, 1930). The infrequent development of the swelling following a standardized operation may be due to variations in

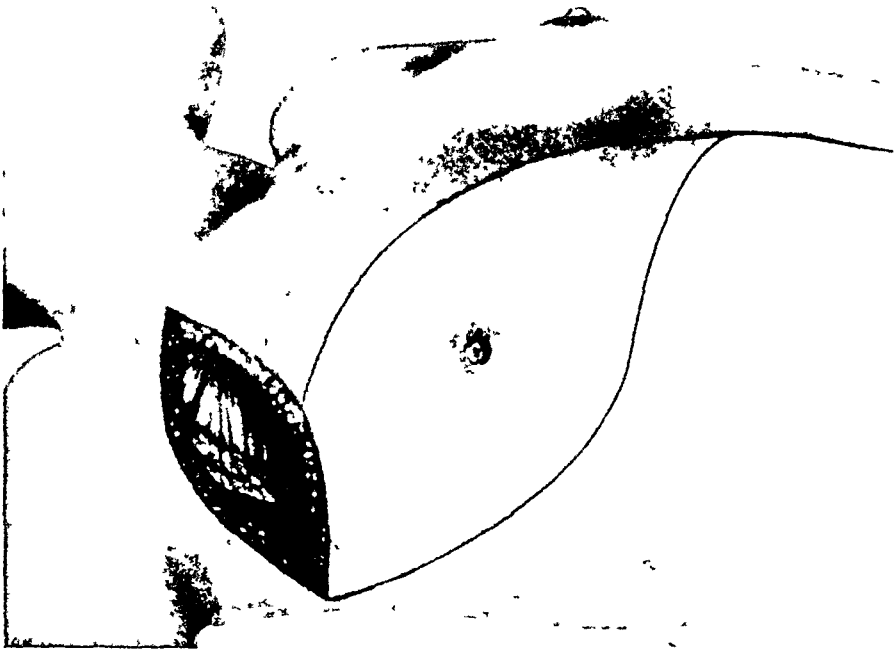


FIG. 1.—The Rodman incision.

the extent to which the main lymphatic trunks draining the upper limb are excised. When too many of the main lymphatics have been removed over too large an area, their regeneration may be inadequate to restore the lymph flow. The delay in onset of the swelling would be due to a combination of partial lymphatic obstruction and loss of skin elasticity."

In a review of 103 radical mastectomies performed on 100 patients, Holman, and his associates, found that the postoperative marked swelling was in direct relation to the incidence of infection which, in their series, was by far the greatest factor. Of 41 patients whose records showed infection, 38 developed swelling, and all 11 patients, in whom marked swelling was noticed, had either early or late infection, or both.

#### PREVENTION

Veal said: "It is easier to prevent postoperative edema after radical mastectomy than to cure it when it has occurred." If the surgeons were willing to focus as much attention upon the preventive measures of this complication as

upon the curative measures of the cancer, a tremendous progress might be registered. It must be clearly stated that the preventive measures, adopted to diminish the liability to postoperative edema, should not jeopardize the curative measures of cancer which constitute, as we have said before, our first consideration in surgery.

In our experience, swelling of the arm following radical mastectomy has been a very uncommon complication. The preventive measures thought to be effective at the Guthrie Clinic are the following: Placing the incision off the arm; a sharp anatomic dissection of the axillary contents; the use of very fine nonabsorbable sutures (we prefer size No. 80 cotton); no drainage; pressure dressing; early mobilization of the arm; and avoidance of infection.



FIG. 2.—Closure without drainage.

We believe that it is very important to keep the incision off the arm; by extending the scar on the arm, there is danger of narrowing the axillary space and interfering with the mobility of the arm; the Rodman incision has been used in our cases with gratifying results (Fig. 1). It affords good exposure and has many other excellent features. At times, the case is found to be inoperable when the axilla is inspected, because such extensive metastases are found. This is best discovered at the beginning of the operation rather than after the breast has been completely mobilized, as is done in any operation which attacks the breast first and the axilla last. In 30 of 680 cases we reported in 1938, the operation was discontinued when the true condition in the axilla was discovered. In controlling some of the arterial blood supply to the breast and the muscles at its source, there is much less bleeding and the breast is handled less in this method, and there is less danger of expressing cancer cells into the circulation.

It is beyond question that trauma is deleterious to the healing of tissues,

particularly fatty tissues, and favors fibrosis and infection. It is suggested that sharp, gentle anatomic dissection should be used throughout the operation. Indeed, the axillary dissection should be carried out with the utmost care.

"While excision of all the lymphatics running from the breast to the axilla is essential, it might be possible deliberately to preserve some of the main lymphatic channels at the upper end of the arm. As pointed out by Gray, Dev-enish and Jessop these main lymphatic channels run in the fatty subcutaneous tissue. "These are, therefore, more likely to be preserved if the subcutaneous

tissue is left in the flaps and their reflection carried by dissection in a plane immediately superficial to the deep fascia on the upper flap from the axilla to a point midway along the clavicle."

Fine and preferably nonabsorbable suture material should be used. We believe that cotton meets all the requirements and is superior to all other types of suture material. It seems unnecessary to stress that the hemostasis should be meticulous and complete.

Drainage is not only useless but is harmful especially if the drain is allowed to lie against the axillary vessels. To put a drain in a mastectomy wound is to provide a beachhead to infection (Fig. 2). Should a serum pocket develop under the flaps, the chances of contamination, by aspirating the serum with a medium-sized



FIG. 3.—Early mobilization of arm.

needle, are less than by inserting a drain at the time of operation to prevent such a collection under the flaps.

The most important factor is undoubtedly the avoidance of infection which plays a definite rôle in occurrence of lymphedema. The factors we have mentioned above, plus absolute asepsis, we believe protect the patient against infection.

Prolonged immobilization of the arm following the operation should be condemned. Absolute free and early mobilization should be instituted. It is as important to mobilize the arm following radical mastectomy to prevent edema as it is to exercise the legs for prevention of phlebothrombosis and thrombophlebitis following operation in the pelvis. The proper application of this measure naturally involves coöperative understanding and action between the surgeon, the patient and the nursing staff. The patient is requested to move her arm as soon as she reacts from the anesthesia. She increases the range of motion until she can duplicate the Statue of Liberty position and until she is able to comb her hair and touch her thoracic spine (Fig. 3).

If roentgenotherapy is indicated, one should avoid a destructive type of dermatitis. While definite clinical experience is lacking, roentgenotherapy may precipitate chronic edema by blocking the lymphatics before collateral circulation takes place by favoring the formation of fibrosis.

Radical mastectomy should not be performed in the presence of infection, no matter how trivial, in the corresponding upper limb. Furthermore, the patient, before leaving the hospital, should be instructed about the importance of avoiding injury and infection of hands and fingers and, should infection, even minor, develop, she should seek immediate medical attention.

We have examined the last 100 living patients subjected to radical mastectomy prior to 1945. Fifty-six of them had axillary metastasis at the time of operation. Postoperative roentgenotherapy was administered to all those with axillary metastases. In 71 patients the wound healed *per primam*, and in 29 it healed by second intention. In six patients the presence of infection was manifest. All these patients were operated upon without primary or secondary skin grafting. Skin grafting, *per se*, does not seem to be a factor in reducing the incidence of lymphedema. Eight patients developed swelling of the arm following operation; in six, the edema has already subsided with conservative measures. Two patients have definite and marked chronic lymphedema; one patient has been operated upon, and her case is included in the list of patients reported in this paper. The other patient has been advised to be operated upon but as yet has not given her consent.

#### TREATMENT

For lymphedema due to a recurrence of the malignancy nothing can be offered other than symptomatic treatment. This paper discusses the treatment of lymphedema where recurrence can absolutely be ruled out as an underlying factor in its production. Here, we no longer can be satisfied with palliative measures.

The few writers who have studied the subject of postoperative lymphedema have either expressed the opinion that no treatment has been devised yet for its relief or have advocated conservative measures such as massage, rest, elevation of the arm at night and the use of an elastic bandage—measures that are not of lasting benefit.

As far as operative procedures are concerned, the Kondoleon operation has proved to be of no value. Standard has obtained an excellent result in one case by excising an oval segment of skin and deep fascia, exposing the bare muscles on the mesial aspect of the arm. The skin of the chest wall opposite the segment was opened through the deep fascia to the muscles (*serratus magnus*) covering the thorax. The skin edges were sutured by interrupted silk sutures and the arm immobilized against the chest wall. While this operation furnished an adequate lymphatic flow, we think the mobility of the arm was greatly restricted. Guthrie and French, in 1942, published an exceptionally simple operative method of treatment, devised by W. C. Beck, of Chicago, for postoperative lymphedema.



It is the purpose of the authors to discuss before the Association, the Beck operation and to report their results in a small number of cases. The method is so safe and so easy to perform, they believe it is justifiable to employ it in all cases where the edema can be proven not to be due to metastases.

"A small incision is made on the arm, about 2 cm. long, which is deepened into the edematous tissue. Into this incision a large eight-inch forceps is introduced. The forceps is pushed subcutaneously as far as it will go, and a second small incision is then made over the tip of the forceps. The tip of the forceps

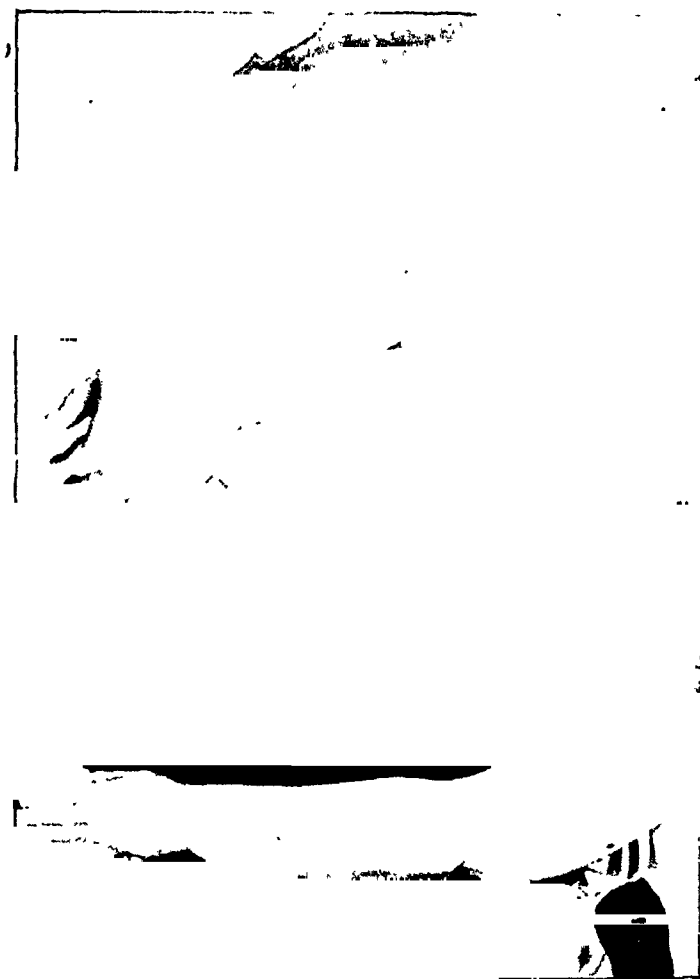


FIG. 4.—Case 1: Preoperative and postoperative.

now grasps a celloidin strip, 1 cm. wide by  $1\frac{5}{16}$  cm. long, and pulls it through. The ends of the celloidin strip are then pushed beyond the incision so that the entire strip lies in the subcutaneous tissue. Usually two strips are used in front and three behind, pushed through the subcutaneous tissue from the arm to the chest. The small incisions are then closed with one or two sutures. The arm is placed on an aeroplane splint, and the strips remain in place for three weeks. At this time, the incision in the normal tissue is reopened and the strips removed. This can be done under local anesthesia."

CASE REPORTS

**Case 1.**—A 59-year-old white female, had had a radical mastectomy ten years previously, in this Clinic, for carcinoma of the left breast, with axillary metastases. Postoperative convalescence was uneventful except for necrosis of the central portion of the wound, which healed by granulation. Within a few months after operation she developed a brawny edema of the arm that increased markedly within the preceding one or two years before admission. Pulmonary symptoms of chest pain and cough had been present for several months and were becoming worse. Roentgenologic examination failed to show



FIG. 5.—Case 2: Preoperative and postoperative.

evidence of metastasis to the lung, and no axillary or supraclavicular nodes were palpated. The arm was greatly enlarged and there was brawny edema from the shoulder to the finger tips, most marked in the forearm. The Beck operation was performed, and within a few days the extremity had shrunk markedly in size. This patient was followed for over three years and the arm remained practically normal in size. Her most recent examination disclosed a late metastatic lesion of the lung, but the arm remained perfect. She died a few months later (Fig. 4).

**Case 2.**—A 48-year-old, white female, who had had a radical mastectomy performed elsewhere, in 1938, for carcinoma of the breast, with axillary involvement. Roentgenotherapy was administered postoperatively, and within three months she developed an

edema of the arm—usual treatment was unsatisfactory. The edema remained fairly stationary for two years, and was mostly in the arm. Brawny edema was present, not associated with recurrent chills or fever, and with no pulmonary symptoms.

Roentgenologic examination failed to show evidence of metastasis to the lungs and no axillary nodes were palpable. The arm was greatly enlarged, and there was edema from the shoulder to the elbow. The skin of the axillary area was pigmented and a long scar on the chest, not extending out on the arm, was present. In May, 1941, an operation, after the method of Beck, was performed, and within a few days the extremity had shrunk markedly in size, by actual measurement. The arm was supported by an aeroplane splint and an elastic bandage was applied for a few days. The celloidin strips were removed after three weeks, and the patient was discharged in good condition. The result in this case was satisfactory for some time. A recent communication reports an axillary recurrence has taken place, the swelling has returned, and that the patient is receiving irradiation (Fig. 5).



FIG. 6.—Case 3: Preoperative and postoperative.

**Case 3.**—A 61-year-old, white female, had had a radical mastectomy elsewhere 25 years before, for what was thought to be carcinoma of the breast. Within a few months her arm became markedly swollen, tense, painful, and produced considerable disability. Her chief complaints were recurrent attacks of severe chills, fever, pain, and increased swelling of the arm. At times, during this period, she had had cough, chest pain and digestive upsets, resembling biliary tract disease. The edema had been constant and there was no recent change in her physical condition. No roentgenotherapy had been administered to this patient, and a history of wound infection at the time of operation was obtained.

Roentgenologic examination failed to show evidence of metastasis to the lung, and no axillary nodes were palpable. The edema was extensive from the tip of the shoulder to the finger tips. The arm was very heavy and the patient requested that the arm be amputated if no relief could be promised her. Operation was performed in June, 1942, and five celloidin strips were placed subcutaneously from arm to chest. The arm was placed in an aeroplane splint and within a few days a remarkable reduction in size and texture of the skin had taken place. The strips were removed three weeks after operation. Three days

later she developed an obscure pulmonary complication characterized by fever, pain and chills, which were thought to be an acute pneumonic process. This was further complicated by a return of her old syndrome of gastro-intestinal upset and chills, without any pain, swelling or change in her arm. The exacerbation lasted exactly two weeks and she recovered as rapidly as she was taken ill. The present condition of this patient is very much improved; the swelling of the arm is lessened, there is some edema however, of the forearm and hand. I am debating whether to employ the Beck principle to connect the lymphatic channel of the forearm with the arm or to use several cotton crochet threads or nylon strips, as advocated by Handley and Ranschoff (Fig. 6).

Case 4.—A female, 57 years old, had had a radical mastectomy performed in this hospital in December, 1936, for carcinoma of the breast. Roentgenotherapy was administered postoperatively. The left arm became somewhat swollen late in 1938, and, Septem-

FIG. 7-A

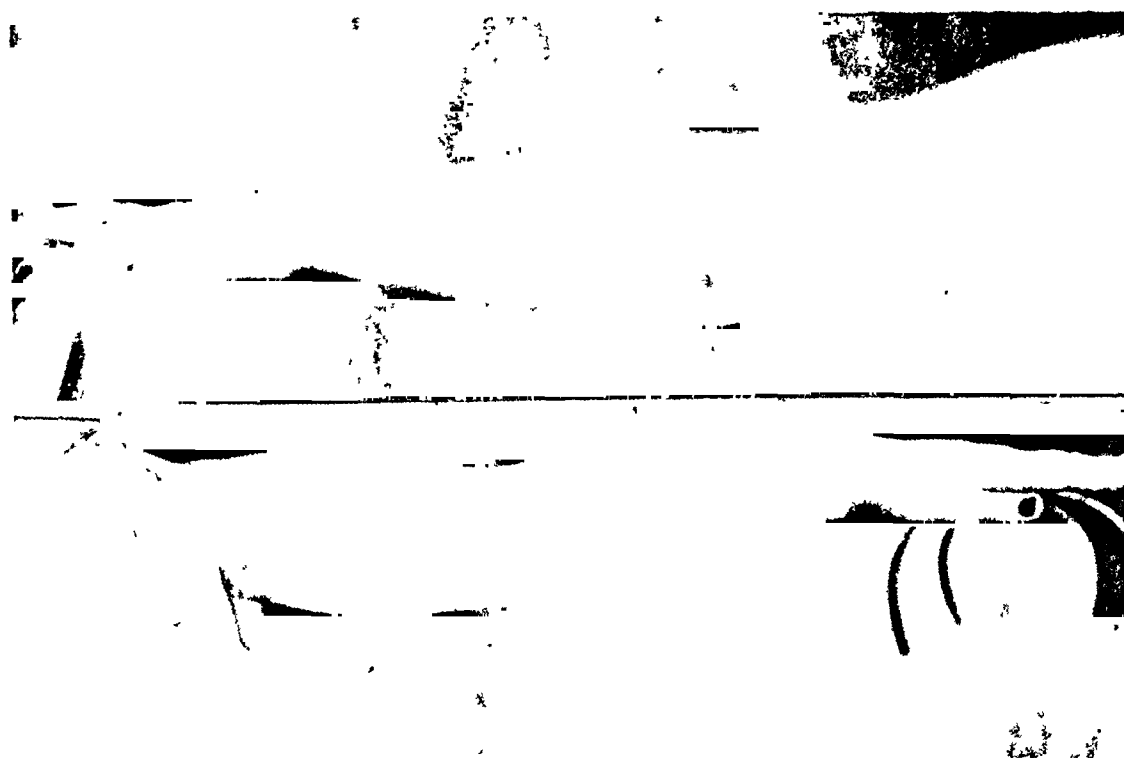


FIG. 7-B

FIG. 7-A—Case 5: Preoperative.

FIG. 7-B.—Case 5: Postoperative.

ber 19, 1939, she was readmitted to the hospital, the diagnosis being postoperative lymphedema. She had no complaints other than pain in this arm. There was no cough and no dyspnea. At this time, there was no roentgenographic evidence of recurrence of the carcinoma and, September 26, 1939 the Beck operation was performed. The celloidin strips were removed in three weeks, and the patient was discharged, much improved. At the time of a reëxamination in this Clinic in April, 1940, the patient's arm was still considerably less swollen than before the operation for the edema, but a roentgenologic examination revealed extensive metastatic pulmonary involvement. A notice of her death, at home, reached us some months later.

Case 5.—A 49-year-old, white female had had a radical mastectomy performed in this Clinic, January 6, 1944, for adenocarcinoma of the left breast. The wound healed *per primam*, and postoperative convalescence was uneventful. Roentgenotherapy was administered postoperatively. Within a few months after operation she developed swelling

of the arm, forearm and hand. The edema increased markedly and became brawny in nature. Chest roentgenograms failed to reveal any metastasis to the lungs, and no axillary recurrence could be detected. On July 25, 1945, a Beck operation was performed. In addition to the celloidin strips, two long cotton sutures, as advocated by Handley and Ransohoff, were buried underneath the skin extending from the wrist to the chest wall. The arm was kept elevated in an aeroplane splint. Two weeks later the celloidin strips were removed and the patient was discharged. At the time of her discharge the edema had subsided a great deal. The patient was seen recently, at which time the arm still remained practically normal in size. This patient is happy and is able to attend parties and do her housework (Fig. 7).

**Case 6.**—A 63-year-old, white female had had a radical mastectomy performed elsewhere six years ago for carcinoma of the right breast. Roentgenotherapy was administered postoperatively. One year after operation she was given another course of roentgenotherapy over her axilla for a questionable axillary recurrence. She developed a very



FIG. 8-A

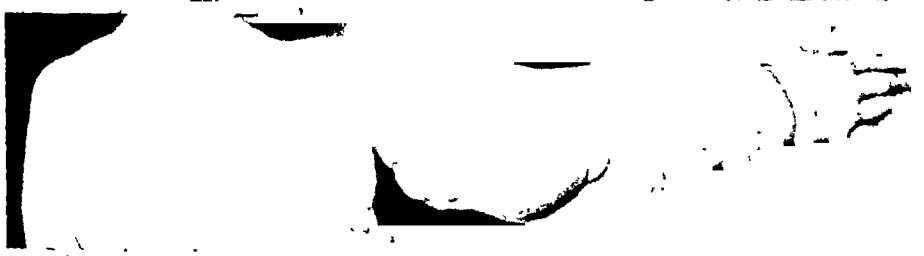


FIG. 8-B



FIG. 8-C

FIG. 8-A.—Case 6: Preoperative.

FIG. 8-B.—Case 6: Preoperative.

FIG. 8-C.—Case 6: Postoperative.

marked swelling of the right arm, of the brawny type, nonpitting. The limb was four pounds heavier than the opposite one, on admission to the Guthrie Clinic. No evidence of recurrence of the cancer could be demonstrated. On August 31, 1945, the Beck operation, with additional burial of cotton sutures, was performed. The arm was kept elevated in an aeroplane splint and within a few days a definite shrinkage of the arm was noted, and was confirmed by measurements. The celloidin strips were removed three weeks later. The patient was submitted to a second Beck operation eight weeks later, hoping to further improve the result. She is still under treatment, and while the arm is much less swollen, the leathery changes in the skin of the axilla and the chest wall are so extensive that it is doubtful just how much further improvement can be obtained (Fig. 8).

**COMMENT.**—Postoperative lymphedema is a distressing but fortunately a

rare complication following radical mastectomy. When of severe degree, it is a crippling, painful and disabling condition. As a matter of fact, some patients have suggested amputation to rid themselves of the disability, the pain and the annoyance.

With such a limited amount of clinical data available it is as yet impossible to draw any definite conclusions concerning the value of the Beck operation in the treatment of lymphedema. Because so very few of our cases develop postoperative lymphedema, we are convinced that the measures we have outlined to prevent its occurrence have merit. This paper will accomplish its purpose if it stimulates interest and further research in this serious and disabling condition.

#### SUMMARY

Certain measures of prevention are described which the authors believe protect the patient from developing postoperative lymphedema.

No definite conclusions can be drawn from so meager an experience, and from the treatment of so few cases. The authors believe, however, because of the infrequent occurrence of arm edema in their cases that the position they take in regard to its prevention is correct.

The Beck operation has relieved a few of our patients, and because it is so simple and safe to perform it should be given a thorough trial.

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DISCUSSION.—DR. CHARLES GORDON HEYD, New York, N. Y.: Doctor Guthrie draws attention to a postoperative complication following a radical mastectomy which is often passed over. I believe that there will always be some lymphedema of the arm after radical resection, and it is due to cicatricial contraction around the axillary vein. For many years I have retained the pectoralis minor and, after careful dissection of all vessels and fascial attachments, have wrapped it under the axillary vein and sutured the distal end to the chest wall. We always leave the arm entirely free and encourage the patient to use the arm actively in every way possible while in the hospital. Instructions are given to continue stretching exercises at home.

I am sure that postoperative roentgenotherapy invariably increases the lymphedema of the arm. In two very severe cases I have employed the Handley operation of lymphangioplasty with considerable success in one, and only a fair result in the other.

DR. J. ROSS VEAL, Washington, D. C.: My interest in this subject came about from studying the venous circulation in patients with primary thrombosis of the subclavian vein. These studies included venograms and venous pressure determinations. In primary subclavian vein thrombosis the clot results from trauma and the surrounding tissues are free from inflammation. The pressure in the arm veins rises rapidly after formation of the thrombus and persists until adequate collateral veins form to relieve the venous congestion. We know that when the venous pressure in the arm is raised above 170 mm. of water, fluid is lost into the tissues, and the amount of edema is in direct proportion to the degree of elevation of the venous pressure. The average venous pressure in the acute stages of subclavian vein thrombosis is about 300 mm. of water.

The point of obstruction and the venous collaterals were easily visualized by venograms. Furthermore, it was shown that as the venous collaterals formed the pressure fell and edema subsided. By applying similar studies to some 60 cases of edema of the arm following radical mastectomy we found that venous thrombosis or venous obstruction was present in more than 90 per cent. Furthermore, the venous pressure in the arm was elevated sufficiently to produce edema. The cause of the venous occlusion may be scar tissue or recurrent malignancy.

One other factor that I think, often overlooked after radical mastectomy, is that the angle of the axillary vein is changed from an obtuse to a very acute angle when the arm hangs by the side. In this position the vein may be completely obstructed. Some relief for these patients may be obtained by carrying the arm away from the side. Ligation of a normal axillary vein at a single point is not likely to produce edema. If, however, sufficient tributaries are also blocked edema will develop.

Doctor Guthrie reports edema in 8 per cent of his cases, but I am sure the percentage will be higher in some hospitals. Infection, scarring and lymphatic blockage must play a part in some cases, but obstruction of the return venous flow is the most important factor in the production of edema.

# REFRIGERATION ANESTHESIA FOR AMPUTATION\*

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THE PRINCIPLES outlined by Allen underlying the use of lowered temperature for the production of anesthesia in the extremities are now widely known and appreciated. Reference to the Quarterly Cumulative Index prior to 1941 shows no clinical reports on this subject; in 1941 there were three references; and in 1944 thirty-five.

The principles set forth by Allen as the result of his experimental work on animals are briefly: heat applied to tissue with an inadequate blood supply is an inexcusable menace because it increases the metabolism of the tissues so treated. This increased metabolism demands an increased supply of oxygen and tissue food and an increased circulation to remove the waste products and toxins of metabolism. Neither of these demands can be met and, therefore, tissue disintegration is hastened. Heat promotes the growth of bacteria and the further extension of infection and gangrene. Lowering the temperature of the tissues reduces the metabolism and, hence, decreases oxygen needs, diminishes absorption and formation of toxins and inhibits bacterial growth. Cold also produces anesthesia. This result was apparently an incidental finding, but was the main factor in the immediate clinical adoption of the refrigeration method.

The work of Allen<sup>1</sup> and others<sup>2, 3</sup> showed, too, that tourniquets could be applied for many hours or days with no harm to the ligated part or to the blood vessels in the constricted area if this part was immersed in ice water or placed in a pack of cracked ice.

At Allen's suggestion these principles were applied by the Surgical Staff of the City Hospital of New York, who reported in amputations for diabetic and peripheral vascular disease a reduction in fatality from 65 per cent to 15.5 per cent. This reduction in the number of deaths occurred in gravely ill, debilitated people, most of whom were over 60 years of age. This improvement they thought was due to the absence of shock during the operation and control of the degree and extent of the infection in the extremity involved. They also considered that the time spent in preparing the patient, which could never be spent prior to the introduction of the "ice method" but which thereafter became available, was valuable. We now believe that this together with control of infection afforded by the method are factors in reducing the death rate even more important than the absence of shock during the operation itself.

McElvenny<sup>4</sup> has recently carried this preparation further by so-called "physiologic amputation" before surgery is performed. With a machine for maintaining and regulating low temperature (Therm-O-Rite) the affected

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\* Read before the Fifty-seventh Annual Session of the Southern Surgical Association, December 4-6, 1945, Hot Springs, Virginia.



limb is frozen solid at a temperature of 10° F. and kept in this condition sometimes for as long as eight weeks. "During this time," he says, "they are comfortable, and the leg for all practical purposes is amputated." When the condition of the patient justifies it, whether this be eight hours or eight weeks, amputation is then done by surgery with or without tourniquet under any suitable general anesthetic. Cold is not continued after the operation.

It is interesting to note that the very factor in refrigeration, namely, anesthesia, which popularized the method and made it "catch on" so quickly, is now being relegated to a minor position,<sup>16</sup> and properly so. It is possible that this freezing may eliminate the tourniquet except as an hemostatic agent. It is important to remember that all frozen tissue must at some later date be surgically removed, for in all such tissue the changes in the cells are irreversible, the cells are killed, while with the tourniquet and temperatures of 33° F. to 40° F. the cells are in "hibernation," all their metabolism has ceased and they are insensitive to stimuli. They return quickly to normal if the refrigeration and tourniquet asphyxia are not maintained for longer than 50 hours for the leg and thigh. The exact limits for the viability of human tissue under these conditions has not yet been determined but as clinical data continue to be recorded these limits will certainly be set. From our own experience we are sure that the limits will vary with the age of the patient subjected to the procedure. We will discuss this below when speaking of minor disadvantages and dangers of the refrigeration method. In those patients for whom amputation is certain the tourniquet and ice pack may safely be left on for days or weeks.<sup>1, 3, 4, 5, 6, 7</sup> Where minor surgery is indicated such as amputation of a toe or finger, incision and drainage of an abscess of foot or hand, excision of an ingrowing toe nail, we have used the tourniquet and ice pack frequently without any damage to the temporarily asphyxiated tissue. Except in those where preparation is important, as in diabetics and patients with arteriosclerosis or cardiovascular disease, other methods of anesthesia are more suitable for minor surgery and much easier to use. But where preparation is so important we believe that the method should be used even in minor surgery as well as for amputations, not only for the control of infection but for the anesthesia as well.

We are in complete agreement with the opinion of McElvenny:<sup>4</sup> "There is no need to hurry in any case and time is gained for the patient to rid himself of his toxins, to greatly improve generally, to be stabilized and built up to a point where he can stand a carefully selected general anesthetic and amputation with ease. In other words, a patient admitted in poor general condition with, for example, an infected gangrenous limb, diabetes, and who is somewhat disoriented, has in the writer's opinion the best chance of survival if infection is held static, absorption of toxins is prevented, and pain eliminated till (*sic*) the diabetes is controlled and the patient is oriented, active and cheerful. At this time, and only then, a general anesthetic by vein or inhalation or both is given and a planned deliberate operation performed.

"To take this same patient in, cool his limb for an hour or more after applying a tourniquet, and amputate as an emergency as soon as the cold has pro-

duced sufficient anesthesia by itself, does not appeal to this writer as sound surgical practice."

Lacking a Therm-O-Rite, or similar machine, we believe the proper method of applying the cold for major surgery is by ice pack and tourniquet for days or weeks, if necessary, then leaving this tourniquet in place and placing a second tourniquet at a high level after cooling for an hour the tissues at this higher level. After three to five hours of this second tourniquet with the limb returned to the ice pack, amputation is then done between the two constrictors. Many observers<sup>4, 7, 8</sup> have used some modification of this method. Haley<sup>8</sup> has devised a box with two compartments for icing the lower leg and the thigh for different lengths of time. We used a single compartment box for icing when we began but we found the box heavy, hard to handle, often leaky, and what was worse the lower margin of the hole in the upper end of the box, through which the thigh passed, often caused chafing and pressure discomfort

TABLE I	
MORTALITY OF THIGH AMPUTATION	
<i>Lexington Clinic Surgical Section</i>	
1932-1942 "pre-ice"	
Amputations, 72.....	Deaths, 12
Fatality, 16 $\frac{2}{3}$ %	
1942-1945 "ice"	
Amputations, 30.....	Deaths, 5
Fatality, 16 $\frac{2}{3}$ %	

to the thigh at this point. We soon abandoned it for the better but not entirely satisfactory rubber sheeting. To those of us who have not tried it the ideal seems to be the controlled dry cold of the automatic machine.<sup>4</sup> But this may seem ideal because we have not yet become acquainted with the possible temperament and vagaries of the machine. Until we are equipped with such apparatus the ice pack and rubber

sheeting with tourniquet will be fairly adequate if enough care is taken in applying the ice and tourniquet, seeing that the patient is dry and does not get out of the pack, examining the leg from time to time to be sure the tourniquet has not slipped, in short, in seeing that he receives adequate nursing.

The technic we have used for the past two years varies according to the severity of the illness. For minor surgery of the foot the patient sits for one hour with his foot or leg in a drum or deep bucket of cracked ice, the level of the ice coming to the knee well above the proposed site for the tourniquet. The rubber constrictor is then applied to the midcalf after blood is drained out by simple elevation for one minute. The foot (and leg) is returned to the ice for one hour and the patient brought to operation with his foot still in the bucket. After surgery, which is completely without pain, the tourniquet is removed, hemostasis carried out, and the wound closed or left open, depending on the nature of the disease for which the operation was performed. Ice bags are continued on the affected part for 24 hours if there has been no infection and longer if the operation has been for abscess or gangrene.

Patients with more extensive gangrene and infection, who are well oriented, in good condition, and if diabetic, the sugar metabolism is under control, we put in bed with the foot, leg and thigh in a pack of cracked ice for one hour. The ice is in direct contact with the skin. Seconal gr. 1.5 is given one-half hour before this. The ice pack consists of rubber sheeting on which is placed a layer of finely cracked ice, the limb is placed on top of this and covered on all

sides and on the anterior surface with a thick layer of cracked ice. The amount necessary varies between 50 and 100 pounds. The rubber sheeting is wrapped around the limb and must be long enough so that its "snout" protrudes through the bottom of the bed. When the head of the bed is raised the water drains into a bucket on the floor placed under the "snout." The ice extends almost to the groin (or axilla). After one hour of this the limb is raised from the pack, the tourniquet is applied to the upper thigh (or arm) and the limb returned to the pack. This is maintained for four hours. From time to time the pack is opened, the ice scraped away and the skin examined. If there is any discoloration or mottling, the tourniquet is removed and replaced more tightly, for the discoloration means a leaking tourniquet and a leaking tourniquet means incomplete asphyxia and insufficient anesthesia. Attempting to determine the efficacy of the tourniquet by feeling for the pulse is futile, as we have never been able to feel pulsation below a badly leaking constrictor.

Recently we have done two operations of midhigh amputation where the tourniquet was leaking and where anesthesia was perfect. In both instances the limb had been in the pack five hours.

The patient is brought to the operating room on a stretcher still in the ice pack; he is lifted out of the pack and the limb is prepared and amputation done without further anesthesia unless the procedure for some reason is obviously causing pain. If this proves so, the operation is continued under nitrous oxide or cyclopropane. Four of our patients have had this supplementary inhalation anesthesia. With two patients the ice pack had been removed by mistake just before the patients were placed on the stretcher to be taken to the operating room. In neither instance was the complete anesthesia affected.

Patients who are more severely ill from infection, diabetes or both, we treat with the ice pack as outlined above but without the tourniquet and with the ice limited to the area below the knee. This pack is kept on for days. Care is taken in elderly sclerotic people to limit the ice to tissues which will be amputated later because we have had three patients, Cases 18, 19 and 28 (Table 11), 81, 77 and 72 years old, respectively, none of whom had diabetes, who received "frost bite," with subsequent sloughing of the skin of the thigh in the area above the amputation. The ice had been in contact with the skin of one. Case 18, only 45 hours, of Case 19, 96 hours, and Case 28, 72 hours. This varies from the experience of others.<sup>4, 6, 8</sup> McElvenny,<sup>4</sup> in discussing the question of how long normal skin can stand the application of ice without disintegration cites one patient, 70 years old, who suffered no skin injury from ice contact for 28 days though his skin was then removed with the part amputated. No tourniquet was used. Another patient, 69 years old, with considerable arteriosclerosis was injured, and after unsuccessful chemotherapy and severe infection in the leg developed was placed in the ice pack without tourniquet for eight weeks. Two days after the ice pack was begun split-skin grafts were used on the raw area. After eight weeks the grafts were growing well and there was no injury to the normal skin.

In spite of this and because of our own experience with three patients we

# REFRIGERATION ANESTHESIA

AN ANALYSIS OF ALL THIGH AMPUTATIONS PERFORMED UNDER "ICE ANESTHESIA"

TABLE II

Race	Sex	Age	Diagnosis	General Condition	Wound	Anes- thetic	Result
1. W	F	73	Diabetes, with gangrene, severe	Poor	Infection 4 plus		Good. Hosp. days, 69. Preop. days, 8
2. W	F	66	Diabetes with gangrene	Good	Primary healing		Good. Hosp. days, 20. Preop. days, 4
3. W	F	75	Sarcoma foot	Good.	Primary	Ice plus N <sub>2</sub> O	Good. Hosp. days, 19. Preop. days, 1
4. W	M	67	Diabetes, with gangrene, severe	B. P. 190/80 Fair.	Primary healing		Poor. Hosp. days, 63. Preop. days, 37. Died 3 months. Autopsy ca. pancreas; not in mortality %
5. C	F	56	Diabetes, with gangrene, severe	B. P. 164/76 Fair.	Infection 4 plus		Good. Hosp. days, 36. Preop. days, 5
6. W	M	73	Diabetes, with gangrene	Good.	Primary union		Good. Hosp. days, 5
7. W	M	59	Diabetes	B. P. 200/106 Good.	Primary	Ice plus N <sub>2</sub> O	Good. Hosp. days, 28. Preop. days, 6
8. W	M	57	Diabetes, with gangrene	B. P. 216/84 Good.	Healing primary		Good. Hosp. days, 38. Preop. days, 18
9. W	F	54	Diabetes, with gangrene, severe	B. P. 138/65 Good.	Infection 1 plus		Good. Hosp. days, 19. Preop. days, 5
10. W	M	77	Diabetes, with gangrene, severe	B. P. 170/90 Good	Healing primary		Good. Hosp. days, 28. Preop. days, 6
11. W	M	57	Diabetes, with gangrene	Fair	Infection 2 plus. Delayed healing		Good. Hosp. days, 30 Preop. days, 6
12. W	F	56	Diabetes, with gangrene, severe	Good	Primary healing		Good. Hosp. days, 77. Preop. days, 25
13. W	F	66	Diabetes, with gangrene	Good.	Infection 2 plus	Ice plus N <sub>2</sub> O	Good. Hosp. days, 23. Preop. days, 6
14. W	M	72	Diabetes. Cardiac	B. P. 138/76	Primary healing		Good. Hosp. days, 22. Preop. days, 6
15. W	M	75	Diabetes, with gangrene	Poor. B. P. 230/110	Primary healing		Died. Hosp. days, 128. Preop. days, 10. Cardiac failure
16. W	M	61	Diabetes, with popliteal aneurysm and gangrene	Good. B. P. 190/110	Primary healing		Good. Hosp. days, 31. Preop. days, 10 Good. Hosp. days, 17.

AN ANALYSIS OF ALL THIGH AMPUTATIONS PERFORMED UNDER "ICE ANESTHESIA"

TABLE II—(Continued)

Race	Sex	Age	Diagnosis	General Condition	Wound	Anes- thetic	Result
17. W	M	70	Arteriosclerosis, gangrene	Good. B. P. 170/80	Delayed healing, with secondary closure		Died. Hosp. days, 115. Precop. days, 47. No permission for amputation until 1 day precop. Cardiac Good. Precop. days, 80.
18. W	F	81	Arteriosclerosis, gangrene	Good. B. P. 190/100	Slough of thigh skin. Ice contact 45 hours precop.		Good. Hosp. days, 110. Precop. days, 10
19. W	M	77	Arteriosclerosis, trauma	Good	Slough of thigh skin. Ice contact 4 days precop.		Good. Hosp. days, 110. Precop. days, 10
20. W	F	66	Diabetes, with gangrene, severe	Good	Delayed healing infection		Good. Hosp. days, 45. Precop. days, 6. 3 operations Good. Precop. days, 45. Died 3rd postop. day. Heart. Precop. days, 6
21. W	M	56	Arteriosclerosis, gangrene	Poor	Primary healing		Died 2nd postop. day. Heart
22. C	F	65	Arteriosclerosis, with heart disease and congestive failure	Poor. B. P. 190/110	Primary healing		Good. Hosp. days, 13. Precop. days, 3 Good. Hosp. days, 28. Good. Hosp. days, 20. Precop. days, 47. as Case 20) Died at home 3 months postop. Heart
23. C	M	73	Arteriosclerosis, with gangrene	Poor. B. P. 240/120. Cong. failure Good, but B. P. 220/110 Poor. Hb. 37%. B. P. 160/105 Excellent	Primary healing		Good. Hosp. days, 21. Precop. days, 5 Ice plus N <sub>2</sub> O
24. W	M	60	Sarcoma (melano) foot	Poor.	Primary healing		Good. Hosp. days, 42.
25. W	M	75	Arteriosclerosis, gangrene	Poor.	Primary healing		
26. W	M	25	Osteogenic sarcoma leg	Poor.	Primary healing		
27. W	F	68	Diabetes, severe	Poor.	Primary healing		
28. W	M	72	Arteriosclerosis, 4 plus	Poor.	Primary healing		
29. W	M	68	Diabetes, with gangrene	Poor. B. P. 190/115	Skinslough after ice contact of 72 hours		
30. W	F	66	Diabetes, with gangrene, severe, foot and lower leg. Temp. 102° F.	Fair. B. P. 190/85 Good. B. P. 130/90	Primary		

follow either one of the following variations: When the patient is not severely ill and where amputation is not certain we follow the advice of our senior partner, Dr. W. O. Bullock, and cover the affected part with ice bags to lower, but not stop, the metabolism in this area. A similar idea is suggested by Allen,<sup>7</sup> who advises in such cases an electric fan to keep the skin of the affected part between 68° and 86° F. At the same time "an accurately controlled heating device is applied from the thigh down below the ankle and maintained at the highest safe temperature, in order to promote hyperemia." This nicely balanced point between heating and chilling seems to us beyond the powers and equipment of the average clinician and we shall continue to use ice bags of thin rubber and possibly add, at Dr. Allen's suggestion, the electric fan.

For the severely ill debilitated wrecks we shall continue to use the two-tourniquet plan. The leg is "amputated physiologically" with a tourniquet below the knee and the leg is kept in ice for whatever time may be necessary for the restoration of the patient's full balance—often this is days or weeks. Of course, permission for amputation must be obtained from the patient or responsible members of his family. When the patient is ready for operation the further course is the same as that for ordinary thigh amputation, namely, ice pack on thigh for one hour, then tourniquet around upper thigh, then return to the ice pack for four hours, followed by mid or low thigh amputation without further anesthesia. The distal tourniquet below the knee, which has been on for days or weeks, is not removed until salvaged from the amputated part.

It is still almost unbelievable to see one of these old, sick people brought to surgery and a midthigh amputation performed with no pain, no fall in blood pressure, no rise in pulse rate, while patient and anesthetist are carrying on a lively conversation. The patient eats a normal breakfast, takes the usual dose of insulin if necessary, and returns to bed and continues his regimen of insulin and diet without any change because of his operation. We close the wound tightly, with one gram of sulfanilamide crystals under the muscle flaps. We use a fish-mouth incision and do not inject the sciatic nerve with alcohol. We use plain catgut throughout, chiefly No. 00 in size, and close the skin with interrupted and continuous sutures of silk. The rubber ice bags are kept on the stump for four to six days and patients are encouraged to be up in a wheel chair the day after the operation. Because healing is slow sutures are not removed for 12 or 14 days unless infection develops in the stump.

The advantages of the "refrigeration method" may be briefly summarized. This procedure almost instantly relieves pain in the affected part; limits the activity and spread of infection; prevents the absorption of toxins from bacteria and tissue; suspends the diseased process until the severely ill patient can be restored to balance by the many and varied means he may require; and in severe trauma and shock<sup>5, 6, 7</sup> not only combats the shock itself but saves anemic and potentially infected tissue otherwise lost by preserving it until collateral blood supply develops, as attested by the work of Mock and Mock.<sup>6</sup> It widens the range of operability to include those gravely ill patients who here-

tofore have been considered hopeless, too far gone for surgery, most of whom under this regimen recover.

It is important to note, here, that refrigerated asphyxiated tissue does not have to be removed if it is not actually frozen and, hence, the method may be used for any operation on the extremities where no amputation is indicated.

Its increasing use for a wide variety of conditions was predicted, and is now being realized in many quarters. It has been used to postpone, and even make unnecessary, débridement in trauma and in burns<sup>7</sup> where it is especially useful in controlling the pain of repeated dressings. "Tedious operating room asepsis" becomes unnecessary because the cold controls infection. Carefully controlled moderate, not radical, refrigeration is now being used in frost-bite and "exposure" gangrene; the preservation of skin grafts;<sup>4, 9, 15</sup> the treatment of various types of insect and venomous snake bites<sup>7</sup> (without tourniquet); and for sudden thrombosis and embolism in the extremities.

In our own experience, we are using the cold pack without tourniquet more and more in the treatment of major and minor infections of the hand and foot, with and without incision and drainage. The case in the care of our colleague, Dr. Allen Grimes, of Lexington, and reported here with his permission, illustrates dramatically the value of ice and tourniquet in a severe gas bacillus infection:

**Case Report.**—A white woman, 57 years old, was admitted to St. Joseph's Hospital June 4, 1944 in the care of Dr. W. M. Brown with a compound fracture of the left tibia 12 hours before admission. Her condition on admission was good, temperature 100° F., pulse 90, blood pressure 130/85. The wound showed no gross evidence of infection and no cellulitis. Ten hours after admission the wound was scrubbed with soap and water, dirty tissue cut away and after reduction of the fracture a stay screw was used to hold the ends in place. This was done by Dr. Brown, and a plaster jacket applied including the foot and knee. Five hours later the patient had temperature 105° F., chill, pulse 120, and shortly thereafter became irrational. The encasement was removed, the foot was swollen and blue. The discolored area, with edema and crepitation, was extending up to the calf. Gas could be expressed from the wound. A tourniquet was applied just below the knee and the leg was packed in ice. Eight hours later the patient was rational, temperature 100° F., pulse 80, and there was no extension of infection above the tourniquet. After 22 hours in the ice pack with tourniquet Dr. Grimes performed a mid thigh amputation under general anesthesia (nitrous oxide) leaving the stump open. The wound was closed after nine days, and she left the hospital three days later, without further incident.

The disadvantages of the method are small compared to the literal saving of life and limb to which so many observers now attest. They may be listed for discussion:

1. The method is "sloppy" and difficult to carry out, troublesome and time-consuming. Merely to state this objection is to answer it, because this same objection can be raised to a great many valuable procedures now accepted and carried out as a matter of routine. Furthermore, the increasing use of automatic cooling machines, soon to be available, will remove much of the drudgery and "sloppiness" of the preparation.

2. The anesthesia may be ineffective, and supplementary general anesthesia

may be necessary when the patient has had food recently. This very minor disadvantage may be avoided by a good tourniquet efficiently applied and by keeping the limb in the pack long enough, four to five hours, before the operation. Furthermore, as the anesthesia produced by cold is now not the most important result of the method, all patients may be prepared for general anesthesia.

3. Ice in contact with the skin of old people may cause subsequent sloughing in skin which should not have to be removed, as it did with three of our patients, above the line of amputation. This might occur also where there is extensive trauma in old people where amputation will not be necessary but where cold is used to limit infection and allow collateral circulation to develop. This difficulty may perhaps be obviated by using the ice in thin rubber bags instead of in direct contact and with the addition of the electric fan. It is probable that machines will so regulate lowered temperatures that we may determine what the skin visibility limits are for each patient.

4. The lower tissue temperature delays healing. This may be met simply by leaving the sutures in longer. It is not yet certain that healing is delayed as skin grafts<sup>4</sup> have been found to grow well with lowered temperatures.

5. The most important objection raised so far is that resistance of tissue is so lowered by the prolonged cold that infection is more likely to take place, and to be more serious when it occurs, after the temperature has been returned to normal. This objection has been raised by Brooks and Duncan,<sup>10</sup> Large and Heinbecker,<sup>11</sup> and Richards,<sup>12</sup> and answered by Allen and by Crossman,<sup>14</sup> and is still unsettled. Even if tissue resistance to infection is lowered by cold, and this is not proved, it is a minor risk compared to the enormous advantages and a risk all are willing to assume who have personally seen patients get well who previously would have died without surgery because the risk of an operation would have been too great.

The death rate in our series (see Table I) for 72 cases is 16% per cent compared with 16% per cent in cases during a ten-year period preceding the "ice" method.

What the statistics do not show is that in the "ice series" no patient was turned down because of the severity of the illness or hopeless condition of the individual. There are fewer wound infections; hospitalization is shorter; and the patients are more comfortable.

An analysis of our six deaths may be of value. In Table II we have listed only those with thigh amputation:

Case 4, a white male, 67 years old, with gangrene of the foot and severe diabetes, had a good result so far as his anesthesia, healing of his stump, and recovery from the operation are concerned, but succumbed three months later from cancer of the pancreas, with liver and peritoneal metastases shown at autopsy. For this reason we have not included him in our death percentage.

Case 14, a white male, 72 years old, had hypertensive heart disease with congestive failure who died of his cardiac condition on his second admission to the hospital four months after his operation. We have included him in our



death percentage because he died from a condition the operation was designed to improve.

Case 17, a white male, 70 years old with arteriosclerotic gangrene and ascending infection, died two months after his operation from cardiac congestive failure. He was in the hospital 46 days before permission was granted for amputation and was in the ice pack without tourniquet six days before operation. This cannot be classed as a preventable death.

Case 22, a colored female, 65 years old, died on the third day after operation from congestive heart failure. This was a poor risk "heart" patient who might have been saved with the "two-tourniquet" method described above. She had marked arteriosclerosis with a gangrenous foot and was kept in the ice pack only two days before operation.

Case 23, a colored male, 73 years old, with arteriosclerotic gangrene of the foot and hypertensive heart disease, died two days after the operation of heart failure. This was a desperately ill old man who possibly could not have been saved by any method. He should have had the advantage of the two-tourniquet method and longer preparation.

Case 28, a white male, age 70, with marked arteriosclerosis and spreading gangrene of the foot. He was kept in the ice pack without tourniquet three days before operation. Except for sloughing of the skin of the stump, which exactly followed the area of contact with the ice, even above the tourniquet, his wound healed well. He was always disoriented, required a catheter and forcible restraint, and was fed by gastric tube for three weeks. He died at home three months after the amputation. He never regained his mental clarity and was always helpless. It is unlikely that any method of treatment would have saved this patient.

It is noteworthy that of our six deaths only two of the patients had diabetes, in neither of whom was this disease a factor (Cases 4 and 14); while of 11 patients without diabetes, there were four deaths, seven of these had marked arteriosclerosis with hypertensive heart disease, and the four deaths occurred in this group. In our series of 19 patients who had diabetes there were only two deaths (Cases 4 and 14)

#### SUMMARY

1. Experimental and clinical work have shown that living tissue is viable when completely asphyxiated (with tourniquet) for many hours if the temperature is kept between 33° and 40° F.
2. Where the tissue is to be removed later (by amputation) this time may be extended to many weeks if necessary.
3. This method of cooling tissue by an ice pack, with or without a tourniquet, stops pain, controls and prevents the spread of infection in an extremity until the patient is properly prepared for surgery.
4. No patient is too hopeless for surgery when prepared by this method.
5. In trauma and embolism (arterial) the ice pack without tourniquet pre-

serves the tissues of the extremity until collateral circulation develops which may make amputation unnecessary.

6. It is useful in minor surgery with the tourniquet where no tissue is to be removed.

7. There is possible danger that cooling may lower the resistance of tissue so that infection occurs more frequently and spreads more rapidly when normal temperatures are restored.

8. A number of uses for the procedure may be found such as the treatment of shock, burns of the extremities, insect and snake bites, and the preservation of skin grafts.

9. It produces complete anesthesia when properly applied so that operation may be carried out without any shock to the patient or interference with his diet and insulin requirements.

10. Anesthesia is minor in importance when compared to the value of careful and thorough preparation of the patient which the method affords.

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# VERTICAL TRACTION: AN AID IN THE SURGICAL MANAGEMENT OF CERTAIN LARGE TUMORS\*

## CASE REPORT

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**Case Report.**—The patient, Mrs. R. B., first came under my observation October 1, 1943. At that time she presented an enormous tumor which hung down from her right buttock and reached the lower limits of the popliteal space. She stated that the growth



FIG 1.—Appearance of the tumor.

first appeared at the age of five like a birthmark and has continued to grow until it reached its present dimensions. The growth extended over the buttock; the involved area reached the level of the iliac crest. Several smaller off-shoots of the mass projected across the midline, as seen in the illustrations. There were no symptoms associated with the growth, nor was her health in any way impaired. She moved about with difficulty on account of the size of the pendulous mass.

A former attempt to remove the growth had been made elsewhere, but the operation had to be discontinued on account of massive bleeding the patient states.

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\* Read before the Fifty-seventh Annual Session of the Southern Surgical Association, December 4-6, 1945, Hot Springs, Virginia.

## VERTICAL TRACTION

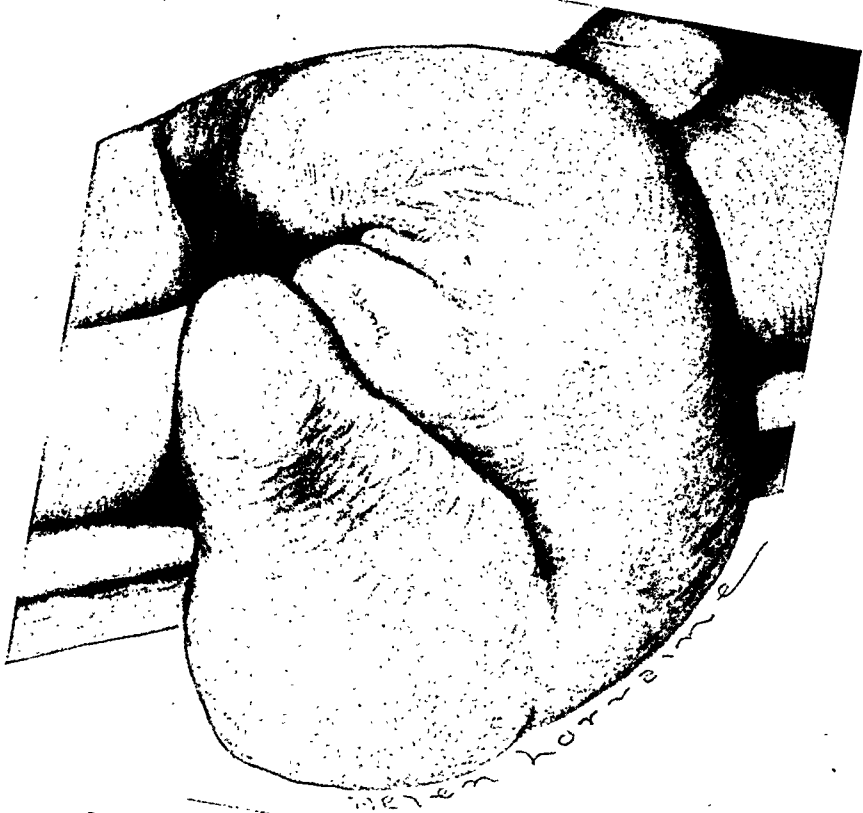


FIG. 2.—Position of patient for operation.

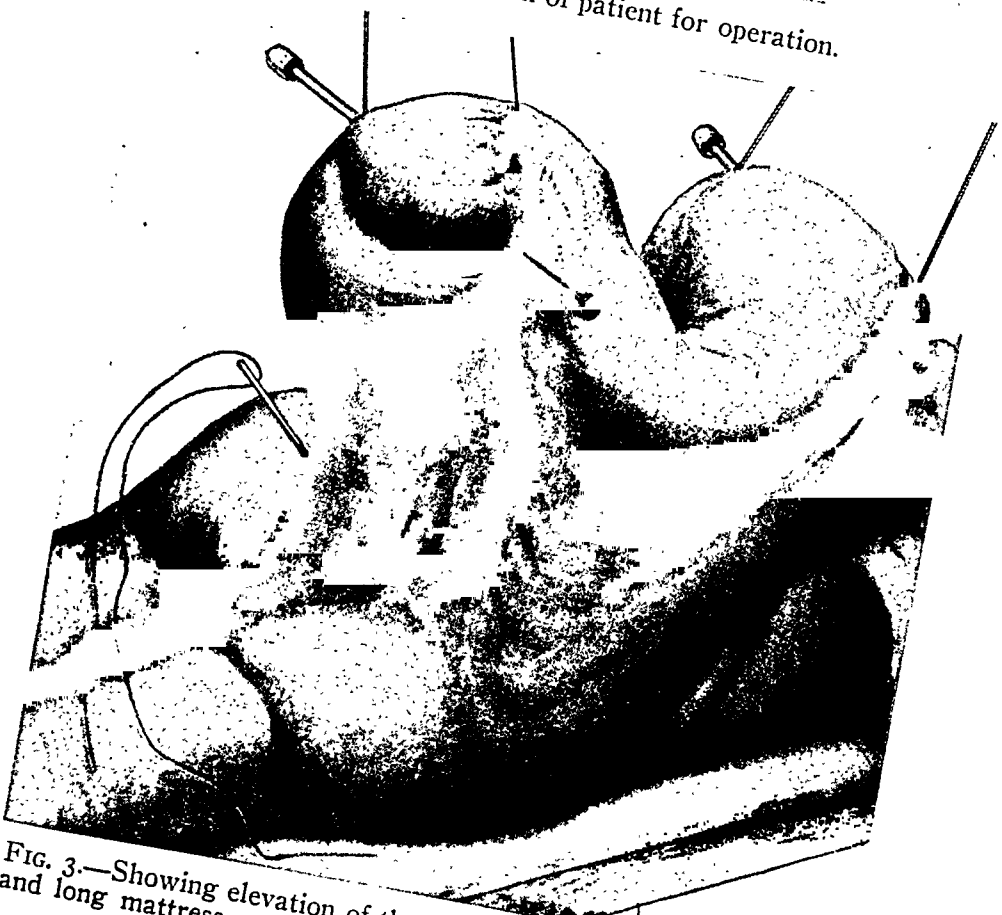


FIG. 3.—Showing elevation of the mass with use of overhead pulleys and long mattress needle for mattressing base to control bleeding.

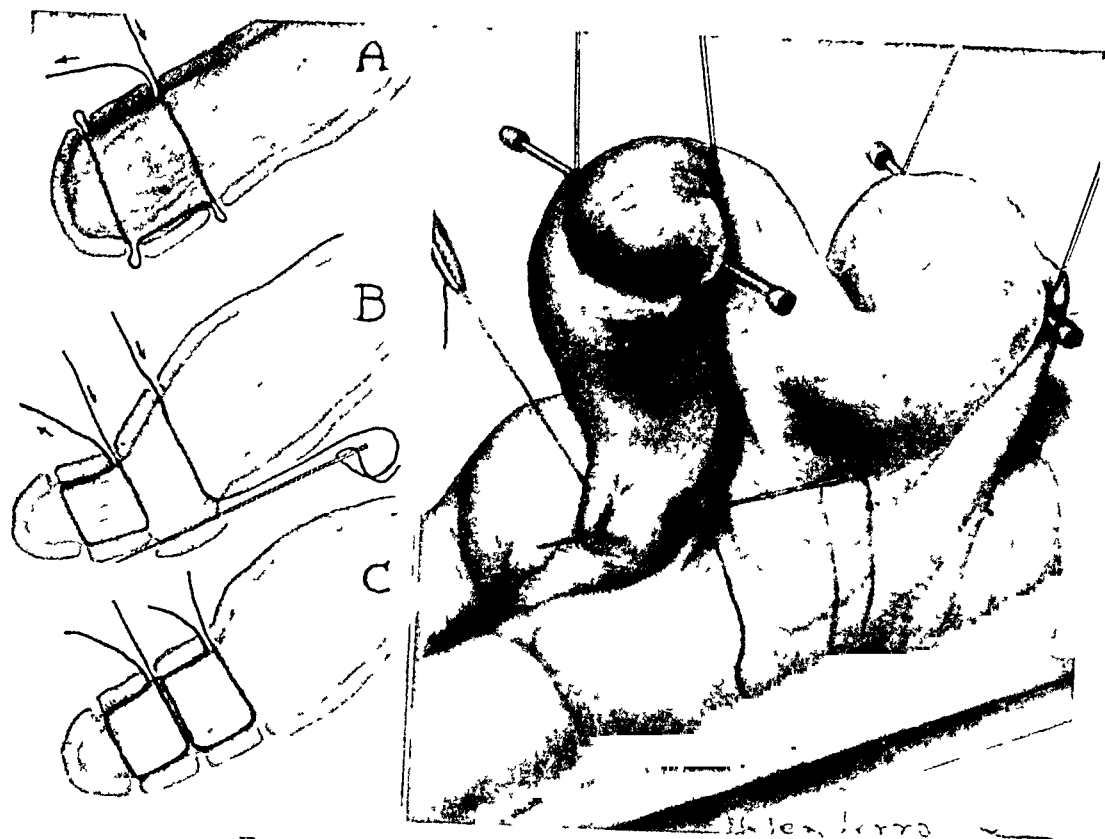


FIG. 4.—Showing procedure for constricting base.



FIG. 5.—Removal of the tumor.

Complete removal of the tumor was obviously impossible but if the dependent part could be removed, it would permit ambulation in a normal manner—at least for a period. The problem was, therefore, one of hemostasis, and preliminary control of hemorrhage until the work could be accomplished. To get at the base of the mass it had to be lifted and held up out of the way. The preoperative diagnosis was hemangioma or lymphangioma.

*Operation.*—October 10, 1943: Under gas-oxygen anesthesia, the patient was placed face down on a Bell orthopedic table with overhead bars, the area was prepared by scrubbing and painting with merthiolate. Two Wyeth pins were pushed through the tumor close to its most dependent limits, sterile bandages were attached to the pins and then carried to two pulleys attached to the overhead bars of the table, the mass was then elevated away from the body leaving the base free; the area was then resterilized and draped. For control of the bleeding it was decided to mattress the base without strangulating the skin, using a long mattress needle with heavy netting cord. The needle was pushed through the base through the skin on the opposite side, then reinserted, pushed beneath the skin to another opening, then back through the tumor, then beneath the skin to the point of starting. This included the tissues at the base for two or three inches. The procedure was repeated some five or six times until the entire base was included in the areas to be constricted. The sutures were then tied and removal of the tumor begun. The operation was almost bloodless until accidentally one of the constricting ligatures was severed. Massive bleeding took place, requiring six pints of blood for replacement. There was a great network of veins imbedded in the fat surrounding the tumor mass. Structurally the growth was a neurofibroma.

Three subsequent operations were performed on smaller projections of the tumor.

At the present time the mass is gradually slipping down, reaching the upper third of the thigh. How long it will take for the growth to reach its former dimensions I do not know—probably several more years.

The technic of overhead traction was found very useful in this case, and it is believed it will find a place in similar cases, and especially does it seem ideal for interscapulothoracic amputations.

These large growths suggest also that we are not using the remarkable ability of the skin to adapt itself to internal pressure and traction. I have in mind the possibility of producing artificial cysts, gradually increasing their size, or by traction of the skin gradually applied, thus, any amount of normal skin might be obtained for any conceivable defect.

*DISCUSSION.*—DR. CARRINGTON WILLIAMS, Richmond, Va.: I would like to thank Doctor Bullock for bringing this very ingenious method before the Association. I recall two tumors where I am sure this method would have facilitated their removal. The first was seen with Dr. William H. Goodwin, and I will never forget the amount of bleeding he had to deal with, but he removed it. The second was a retroperitoneal sarcoma weighing 54 pounds. If we had had this overhead traction I would not have been so tired after helping Dr. Stewart McGuire remove it.

DR. ISIDORE COHN, New Orleans, La.: I cannot miss the opportunity to mention a case Dr. Matas had about 20 years ago, a woman with Recklinghausen's disease who had one tumor that hung from her neck like a snood, weighing more than 100 pounds. The woman could not get around. He decided to take it off. He got a large pair of ice tongs, had a pulley and rope attached on the roof of the operating room, tied to the observation rails in the operating room, and he successfully removed it. It was one of the most remarkable things I ever saw. I do not know whether he used the prophylactic hemostatic sutures.

# THE TREATMENT OF SEBACEOUS CYST BY ELECTROSURGICAL MARSUPIALIZATION\*

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LIKE THE POOR, the sebaceous cyst we always have with us; and if we consult the textbooks, the treatment recommended is, invariably, simple but complete excision. Yet, in spite of the greatest care, rupture of the cyst during excision, and recurrence is not so rare. In such regions as the upper back, the firmness of the tissues makes good cosmetic closure of the resultant cavity after excision difficult, and the pull against the suture line of ordinary bodily activity, even in the reclining state, often results in pulling apart of well-placed sutures, and healing by granulation and scarring. On the face, the female breast and anterior chest surface, while the tissues lend themselves to good approximation, failure of primary union is not infrequent, resulting in tell-tale scars.

A report of the application of a new principle, or rather the use of an old one, to the cure of sebaceous cyst that seems to compare quite favorably in percentage of cures and cosmetic results, will perhaps not prove too trivial a matter to consider.

Last January, I reported 20 cases treated by this method.<sup>1</sup> I have treated 12 additional ones since. They were situated on the face, neck, scalp, back, breasts and surrounding areas, deltoid region and a high thigh amputation stump. They ranged in size from 1.5 to 6 cm. Nearly half were inflamed, about to rupture, or were associated with an adjoining abscess.

## TECHNIC

A sharp needle is inserted into the center of the top of the cyst so that its point barely protrudes into the cavity (Fig. 1) and the diathermy current is turned on until a whitish eschar is seen to form around the needle. This takes from two to five seconds. If the needle is inserted too deeply the force of the current is dissipated in the cyst contents and no cauterization results. The diameter of the slough produced should be approximately one-fourth that of the cyst itself. One puncture is sufficient with cysts up to about 3 cm. in diameter. Two or three adjacent punctures will be required with the larger cysts. The center of the top of the cyst is the preferred point of puncture, for here the combined thickness of skin and cyst wall is thinnest, there being no fat or areolar tissue intervening. A puncture away from the center would result in a much thicker slough with the possibility that cicatricial closure might

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\* Read before the Fifty-seventh Annual Session of the Southern Surgical Association, December 4-6, 1945, Hot Springs, Virginia.

# THE TREATMENT OF SEBACEOUS CYST

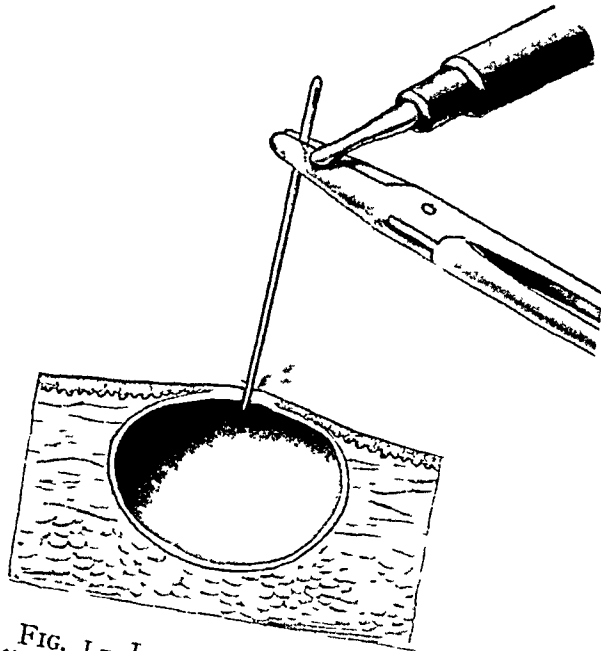


FIG. 1.—Insertion of the needle and application of the electrode as the current is turned on.

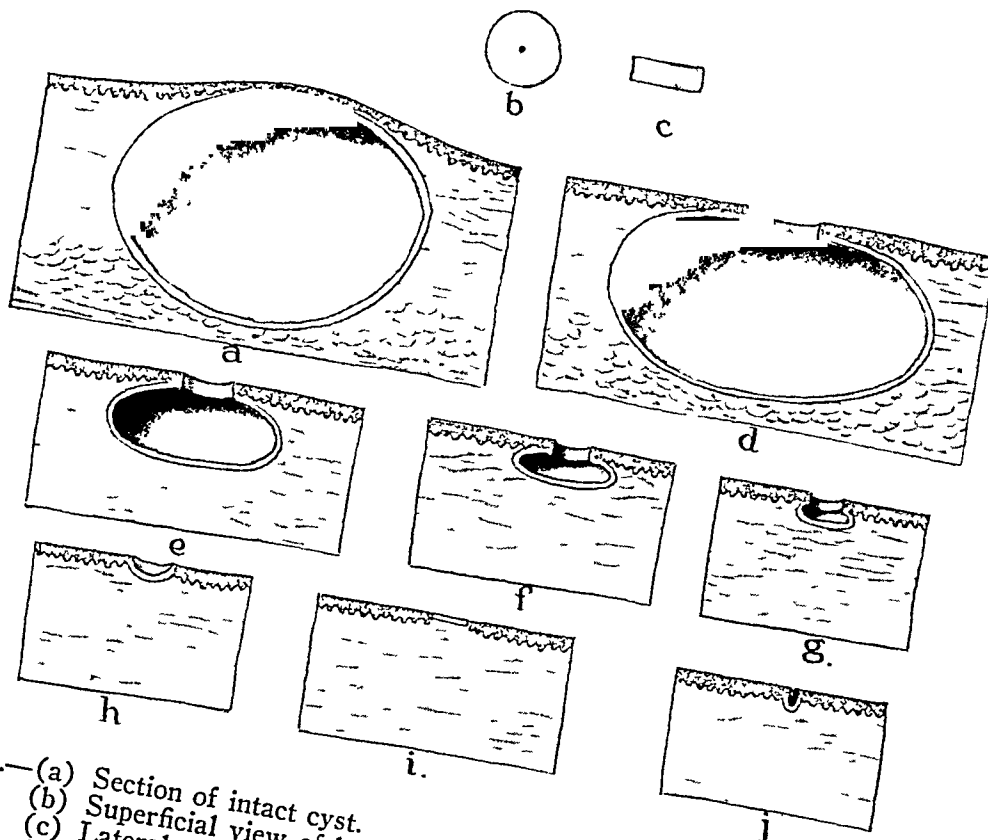


FIG. 2.—(a) Section of intact cyst.  
(b) Superficial view of button of tissue which sloughs out.  
(c) Lateral view of (b).  
(d) Cyst after slough has separated.  
(e, f, g, h) Various stages of diminution in size of cavity.  
(i) Final leveling off of cyst wall, the usual result in uncomplicated cases.  
(j) The result in six cases following previous excision or preoperative inflammation and infection.

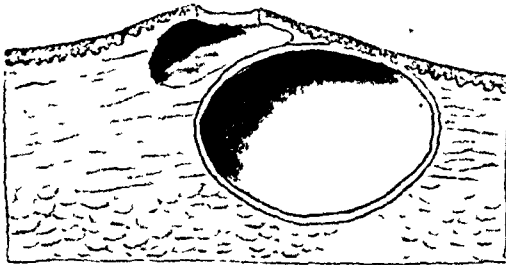


ensue before skin and cyst wall epithelium had time completely to cover the entire edge of the resulting opening. Where the cyst has become infected and possibly ruptured into the surrounding fat, it may be difficult to judge just where the thinnest area over the cyst proper actually lies. The needle may be inserted into an adjacent pus cavity (Fig. 3a) in which case the opening will promptly close, necessitating a second treatment with the needle properly placed. The unipolar desiccating current of the office diathermy machine was used for the smaller lesions and the bipolar coagulating current from the same machine for the larger ones. The current is barely strong enough to produce the necessary desiccation or necrosis, the patient experiencing a sharp stinging

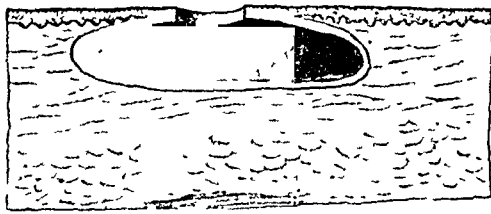
sensation that is easily borne for the few seconds required. In only three nervous individuals was it necessary to use a 1 per cent procaine injection in the surrounding skin.

At the end of five to eight days a button of necrotic tissue sloughs away, leaving an opening the surrounding edges of which are firm, indurated, and the margins inflamed.

In the course of the next three to six weeks, the cyst gradually empties itself, the cavity gets smaller and smaller till the bottom of the cavity finally presents on the surface and soon levels off in a straight line with the surrounding skin showing as a pigmented area which later assumes all the qualities of the skin. There is no drainage of any consequence during this time. In about one-third of the cases there was a tendency for this pigmented area to dimple, reverting as it were to the original shape of the sebaceous gland from which it sprang,



a.



b.

FIG. 3.—(a) The result where the needle was inserted over the top of an adjacent abscess.

(b) Persistence of cavity in case in which hard mass of inspissated cells had to be forcibly squeezed out before cavity diminished in size and finally closed.

resulting in what looks like a large blackhead which is easily kept empty and clean. This latter condition nearly always resulted when the cyst had recurred in an old scar, or where rupture from infection had occurred or was imminent at the time of treatment. In two instances this dimple was quite marked and definitely unsightly. It is hoped that further experience will enable us to avoid a repetition of such a result. In two cases the contents of the cyst were hardened into a compact mass and had to be squeezed out forcibly before the cavity would close.

A glance at Figure 1 will show that the tissue margin at the line of separation after the disk of necrotic tissue has separated is very thin. During the

few days required for this separation there is considerable inflammatory infiltration of the tissue surrounding the line of demarcation so that when the slough separates the surrounding tissue is rigid and has no tendency immediately to permit the opening to diminish in size.

There now ensues a race between the tendency of the opening to cicatrize in a circular manner and close, on the one hand, and of the epithelium of the skin and that of the cyst wall to bridge the thin edge of the circular opening, on the other hand. Since the distance to be covered by the two advancing lines of epithelium is very short, the epithelium wins out, and once the entire circumference of the opening is covered with epithelium there is then no further tendency to cicatricial closure of the opening. Meanwhile, the contents of the cyst are free to drain out and actually do so. But what is most remarkable is the fact that in the uncomplicated case the cyst cavity gets smaller and smaller till the bottom of the cavity finally presents on the surface and straightens out in a straight line level with the skin, and takes on all the qualities of skin (Fig. 2 a, e, f, g, h, i). How this is brought about I find it hard to understand, for some of these cavities were 6 cm. or more in diameter. Is it due to the tendency of the cavity to resume its original size as part of a sebaceous gland, or to the massaging action of pressure on the surrounding fat and aerolar tissue, or both? Perhaps with time and more experience these facts will finally be cleared. In the presence of an old scar to which the bottom or side of the cavity may have become fixed, dimpling occurs, resulting in a tubular final result (Fig. 2 j). While the first case was treated five years ago, there has been no known recurrence. Two patients have returned for the treatment of a second cyst having no relation to the first one. I feel that the cautery effect of the treatment is essential to producing the desired result and that simple knife excision of a button of tissue would not be so successful. I have not tried simple knife excision. There is probably nothing really new about either marsupialization or the use of a cauterizing agent for this purpose. I can imagine Hippocrates poking a hot iron into the center of a large sebaceous cyst and getting a fine result.

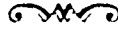
#### REFERENCE

- <sup>1</sup> Danna, J. A.: A Simple Treatment for Sebaceous Cyst. *N. O. Med. & Surg. Jour.*, 98, No. 1, 5, July, 1945.

DISCUSSION.—DR. A. B. MCGRAW, Detroit, Mich.: As I listened to this paper and looked at the lantern slides, it occurred to me that we should keep in mind the warning of the late Doctor Bloodgood, member of this Association, that especially in elderly patients these cysts are likely to be complicated by basal or squamous cell carcinoma. He advocated their complete extirpation. In connection with the difficulty of excising such cysts without rupture and extrusion of contents, the shaping of one's incision so as to include a very narrow ellipse of skin surrounding the epidermal attachment of the cyst and the use of that bit of skin as a handle, make it unnecessary that any instrument touch the thin wall of the cyst itself.

In conclusion, I have been coaxing myself all afternoon to have the temerity to discuss one other matter, connected with this meeting as a whole. There have been

many visitors here these past three days. On behalf of all of us who have been your guests I venture to express our sincere appreciation for the warmth of your hospitality and the stimulus of the presentations on this program; our admiration for the splendid military record of your Association throughout these four terrible years of war; and the added confidence we have gained from knowing that we share with such men as you the task of making the fragile peace into which we have emerged, a more enduring structure than the false millennium on which the world too naively embarked a quarter of a century ago.



## ANNOUNCEMENT

### THE EDWARD D. CHURCHILL LECTURE FOUNDED BY THE EXCELSIOR SURGICAL CLUB

A GROUP OF SURGEONS, who formerly served as members of the U. S. Armed Medical Corps in the North African and Mediterranean Theaters of Operations, recently organized The Excelsior Surgical Club. Patterned somewhat along the lines of the Eclat Club which, in a comparable manner, grew out of World War I, The Excelsior Surgical Club has as its objectives the promotion of the social intercourse of the members and the advancement of their knowledge of the science of surgery.

A principal and outstanding activity of the Club is to be the Edward D. Churchill Lecture honoring the former Surgical Consultant of those Theaters, Dr. Edward D. Churchill, John Homans Professor of Surgery at Harvard University. The Lecture, to which the medical public will be invited, will form an integral part of each annual meeting. The Club plans that each Lecture will be a foremost scientific presentation. To that end, Dr. Alfred Blalock, Professor of Surgery, Johns Hopkins University, has been secured to give the first Churchill Lecture at the first regular meeting of the Club in Boston on October 25-26, 1946.

# MEMOIRS

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ROBERT TUTTLE MORRIS, M.A., M.D., F.A.C.S.

1857-1945

ROBERT TUTTLE MORRIS, widely and affectionately known as "Bob Morris," was born at Seymour, Connecticut, May 14, 1857. The Morris genealogy extended from earliest colonial times. His father was a distinguished lawyer,



Robert Tuttle Morris

a Judge of the Probate Court and later Governor of Connecticut. The maternal side of his ancestry was equally distinguished, his mother, Eugenia Laura Tuttle Morris, being a well-known authoress.

Doctor Morris received a liberal education, with a strong admixture of the classical, at the Hopkins Grammar School at New Haven and later was engaged in biologic studies at Cornell University from 1875 to 1879. He was graduated

from the College of Physicians and Surgeons of New York in 1882, and became a member of the House Staff of Bellevue Hospital from 1882 to 1884. After his internship Dr. Morris studied in various surgical clinics in Europe and in 1884 met Lister in London, a visit that was to exert a profound influence upon his life work and provided the background and knowledge for his first book, "How We Treat Wounds Today," published in 1886. Doctor Morris was among the first to adopt Listerism and did much to awaken the profession to a new era in surgery. It is interesting to note that Lister visited the International Medical Congress in Philadelphia in 1876, the year Doctor Morris entered Cornell University. Somewhat later, in 1880, Samuel D. Gross—the Emperor of American Surgery—was to refer to Lister as "the famous reformer of the surgical treatment of wounds." Within ten years of Lister's visit to the United States and two years after a visit to Lister, Doctor Morris demonstrated a remarkable degree of surgical foresight and in his treatise clearly indicated the future acceptance of antiseptic surgery.

In 1889 Doctor Morris became Instructor in Surgery at the New York Post-Graduate Medical School and from 1898 until 1917 occupied a chair in Surgery and the position of attending surgeon in the Hospital. He was a brilliant speaker and a distinguished writer—two qualities that procured his early advancement and maintained his celebrity.

With the passing of time Doctor Morris' merits as a surgeon have tended to be obscured by his more facile gift for writing and by his great ability as a phrase maker. Yet, he was always a trained surgeon and enjoyed a large practice in an epoch of great individualism in surgery. His patients came from all parts of the United States and South America. Amongst his colleagues he was sometimes considered somewhat unorthodox in his surgical philosophy and pronouncements. It is safe to say, however, that many of his aphorisms will remain longer in the literature and memory of American surgery than his more substantial surgical contributions.

"The last living thing on earth will most certainly be a microbe."

"Toxic insignia left upon the peritoneum."

"Nine specialists to make one doctor."

"Cobwebs in the attic of the abdomen."

"The invalidism of the pelvic reflex."

These and many other surgical cliches had wide acceptance in his time and some are still current today.

Doctor Morris was always an interesting and impressive figure in the surgical clinic. His chief purpose was to arouse the attention of his students, to stimulate them to think. His case presentations were rarely logical expositions but rather entertaining and dramatic, interlarded with an abundance of surgical aphorisms. He used irony to arouse attention and had a sly and subtle wit. Sarcasm was not in his speech and he was always a worthy opponent in medical debate. Doctor Morris possessed in a singular degree serenity, urbanity, dignity and restless curiosity of mind. He was a fluent lecturer on widely diverse subjects; his spirit and his mind were attuned to the rapid evolution not only of medicine but also the cognate sciences.

He passed his professional career almost entirely at the Post-Graduate Hospital. He was a member of most of the national societies. He was admitted to membership in the American Association of Obstetricians and Gynecologists in 1890 and became President in 1907. He was elected a member of the Southern Surgical Association in 1900 and became a senior fellow in 1923. Doctor Morris was also President of the American Therapeutic Association in 1916, and was for many years President of the Physicians Home, Inc., of New York, for aged physicians.

After "fifty years a surgeon" Doctor Morris retired to his estate near Stamford, Connecticut, on his 440 acres of woodland where he spent his retirement in cross-grafting nut-producing trees. His place became a sanctuary for birds and wildlife. It is as an author that Doctor Morris will be chiefly remembered. Among the round dozen of his books were: "Lectures on Appendicitis," "Hopkins Pond," "Dawn of the Fourth Era in Surgery," "Tomorrow's Topics Series," "Microbes and Men," "A Surgeon's Philosophy," "Doctors Versus Folks," "The Way Out of War," "Nut-Growing," "Editorial Silence," and the last "Fifty Years a Surgeon."

There was a continuous curiosity in his mind associated with a persistent skepticism. There was an urbanity and equanimity in his intellect—always of high order. There was poetry in the dexterity of his hands and music in his heart, as is apparent in the last paragraph he wrote: "Bright sunshine lights the evening sky once more and high peaks glow, but soon long shadows steal down to darkening vales for night and deeper dark. 'Tis then I am a mountaineer, and yet at times, when all is still, I seem to hear loud surf—but that is only memory for one who loves the sea."

CHAS. GORDON HEYD, M.D.

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## ROBERT DUVAL JONES

1898-1945

It is with profound regret that I attempt to record the passing of Dr. Robert DuVal Jones, who was an able and conscientious surgeon and a member of the Southern Surgical Association.

Doctor Jones was born in New Bern, North Carolina, October 7, 1898, and died September 4, 1945. He was the son of Dr. Robert DuVal Jones of New Bern, North Carolina. He received his collegiate education at the University of North Carolina and graduated in medicine at the University of Pennsylvania in 1924. He served an internship at the Robert Packard Memorial Hospital, in Sayre, Pennsylvania. Following this he was a Surgical Fellow at the Mayo Clinic, where he was ably trained over a period of four and one-half years.

In January, 1930 he came to Norfolk, Virginia, and was my associate thirteen years. At this time in his career he sustained a severe coronary occlusion and remained bedridden about ten months. His recovery from this cardiac catastrophe was most satisfactory and he returned to Norfolk to engage in private practice of surgery, where he was active and during the great stress of war and the shortage of surgeons, he accomplished professional undertakings that were a great strain and hazard on his physical reserve. In August, 1945, while on a vacation in the mountains of North Carolina, he underwent another severe coronary occlusion which resulted in his death ten days later.



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Robert DuVal Jones

Something of his devotion to his profession, one suspects, played a part in his determination, after earlier ill health, to return to as much practice as he could handle under conditions which required that he take unusually good care of himself but when the abilities of men like him were badly needed in a community which temporarily lost many of its physicians to the war needs. He was too intelligent not to know the risk, but it seems probable that he would not have been content with doing anything less than his utmost in the circumstances and that he felt he must go ahead with the surgery for which he was admirably prepared.

The death of such a man, at an age when he is in the full stride of his career, and when both he and the people among whom he lived can ordinarily look forward to many years of usefulness, is peculiarly tragic. He might have had much ahead of him. Those who knew Doctor Jones best have the added loss of a man of fine feeling, of keen taste and discrimination for the subjects which interested him outside his work, and of a friendly courtesy which made him an unusually pleasant companion.

R. L. PAYNE, M. D.

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## GERRY ROUNDS HOLDEN

1874-1945

A NATIVE of Concord, N. H., Dr. Gerry R. Holden spent the years before settling in Florida securing a thorough preparation for the work which he was to carry on for four decades in his adopted state. After graduating from Yale University in 1897, he entered the Johns Hopkins Medical School and received the degree of Doctor of Medicine in 1901. Immediately thereafter he studied in Berlin for several months before beginning his hospital training at the Roosevelt Hospital in New York. When he had completed the service there, he became a member of the Gynecologic House Staff of the Johns Hopkins Hospital at Baltimore, where he served as resident.

In 1905, when Dr. Holden located in Jacksonville, Fla., the facilities for practicing medicine in the state, so new to him, were not far from primitive in comparison to those of the clinics in which he had been working. In his chosen profession of gynecology he became truly a pioneer in Florida.

Soon after his arrival his good influence on hospital staffs began to be felt. Within a year, he was a member of the staff of St. Luke's Hospital in Jacksonville and also of the staff of the State Hospital for the mentally ill at Chattahoochee. As the years went by, he became gynecologist for the Duval County Hospital and consultant for the Riverside Hospital in Jacksonville, and consultant for the Flagler Hospital in St. Augustine.

When Dr. Holden returned home from military service in World War I, the possibilities of the use of radium in the treatment of gynecologic conditions so appealed to him that he prepared himself and obtained the equipment for treatment with radium. For the last twenty-five years of his life, his practice was restricted almost wholly to this line of work. While carrying on a very active practice, he presented before local, state and sectional societies many valuable papers based upon a broad and long-continued experience in the use of radium.

During the later years of his life especially, there was hardly a movement for the betterment of medicine in his state in which Dr. Holden did not have an active and outstanding part. At one time, he was President of the Duval



County Medical Society, the Florida Medical Association and the Southeastern Surgical Congress. As a founder Fellow of the American College of Surgeons, he appreciated the worth of the standards set by this organization. From the very beginning he was constantly active in the affairs of the College. He was also a Fellow of the American Medical Association and a member of the Southern Medical Association, the Southern Surgical Association and the South Atlantic Association of Obstetrics and Gynecology. He was held in the



Gerry Rounds Holden

highest esteem by the profession, and his friends among its members were legion.

Revered alike by the laity, Dr. Holden not only engaged in his many medical activities but also devoted much time to the work of his church. He served for thirty years as an official member of the Riverside Presbyterian Church of Jacksonville and twice was a delegate to the General Assembly of the Presbyterian Church at Montreat, N. C.

He is survived by his widow, Mrs. Anne Millikens Holden, and one daughter, Miss Katherine Holden, of Jacksonville, and one son, Gerry R. Holden, Jr., and two grandchildren, of Hartford, Conn.

EDWARD JELKS, M. D.

WILLIAM FARQUHAR SHALLENBERGER

1881—1944

IN THE passing of Dr. William Farquhar Shallenberger the Southern Surgical Association lost a most valuable and beloved member. His death occurred at the Piedmont Hospital in Atlanta, on December 16, 1944, after a



William Farquhar Shallenberger

brief illness. However, his health had been such that he had given up active practice five and a half years previously. His widow, Mrs. Laura Boyd Shallenberger, died April 2, 1946. He is survived by a daughter, Mrs. A. E. Gossett.

Dr. Shallenberger was born in Greensburg, Pennsylvania, on July 25, 1881, the son of the late Frank and Emma Shallenberger. He was graduated A.B. from Washington and Jefferson College in Pennsylvania, in 1903. The following year he matriculated in the Medical School of Johns Hopkins University, from which he graduated with honor in the class of 1907. Upon graduation he was given an appointment as intern in the Johns Hopkins Hospital. On the staff at the time were such notables as Drs. Howard A. Kelly, Thomas S. Cullen, Guy L. Hunner, J. Whitridge Williams, W. H. Welch, W. S. Halsted and William Osler. It was Dr. Shallenberger's good fortune to have

studied under these outstanding physicians and their teachings had a great and lasting influence on his professional life. After completing several years as intern at Hopkins he became resident gynecologist in the Woman's Hospital, in Baltimore, where he served two years.

In 1911, he came to Atlanta to locate and entered into the practice of gynecology, obstetrics and abdominal surgery. He soon established an enviable reputation in this specialty and rapidly built up a large practice. As a disciple of Drs. Kelly and Hunner he was among the first in this section to emphasize female urology in gynecology. In 1913, he married Miss Laura Boyd, of Savannah, a sister of his friend and classmate, Dr. Montague L. Boyd, urologist of Atlanta.

Shortly after locating in Atlanta, Dr. Shallenberger became actively associated with the Piedmont Hospital where he did the great majority of his work. He gave much of his time and talent toward raising the standards of this institution and until his retirement was Chief of the Obstetrical and Gynecological Service there. He was Associate Professor of Gynecology in the Emory University Medical School for many years. Later he resigned this position and became Chief of the Department of Obstetrics and Gynecology at the Grady Hospital, white unit. He loved the association of the interns and younger men and gave unstintingly of his time and energy in these teaching positions. He was a member of the Fulton County Medical Society, Medical Association of Georgia, American Medical Association, Southern Medical Association, Southern Surgical Association, Southern Interurban Gynecological and Obstetrical Society and a Fellow of the American College of Surgeons. He belonged to Phi Delta Theta, Alpha Omega Alpha, and was an honorary member of the Alpha Kappa Kappa medical fraternity. He wrote several valuable papers on gynecologic and urologic subjects. He was a member of the First Presbyterian Church, in Atlanta, and also held memberships in the Capital City Club and Piedmont Driving Club.

After his forced retirement from active practice, Dr. Shallenberger refused to remain idle and during the crisis of war worked daily at the office of the Rationing Board, a position without remuneration and requiring much time and energy. He will be remembered by those who knew him best as not only a capable surgeon, but as a refined, cultured gentleman who had great courage and determination and a high devotion to the ideals of his profession.

FRANK K. BOLAND, M.D.

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## EXARTICULATION OF THE LOWER EXTREMITIES FOR MALIGNANT TUMORS:

### HIP JOINT DISARTICULATION (WITH AND WITHOUT DEEP ILIAC DISSECTION) AND SACRO-ILIAC DISARTICULATION (HEMIPELVECTOMY)

GEORGE T. PACK, M.D., AND HARRY E. EHRLICH, M.D.

NEW YORK, N. Y.

FROM THE MIXED TUMOR SERVICE, MEMORIAL HOSPITAL FOR CANCER AND ALLIED DISEASES, NEW YORK, N. Y.

THE MANAGEMENT OF MALIGNANT TUMORS of the extremities often entails amputation. Of the various amputation technics for treating extensive cancers of the extremities, disarticulation of the entire limb in selected cases gives promise of becoming the most effective.

Disarticulation of the shoulder joint is a commonly performed and well-recognized operation which is resorted to more often for traumatic, infectious and other nonneoplastic conditions and will not be considered in this study. Hip joint disarticulation, although less frequently employed, is of distinct value in the treatment of malignant tumors. The present report will deal with its indications, technic and end-results. In addition, the surgical principle of exarticulation of an extremity with excision of the regional lymph nodes for malignant tumors will be introduced, together with a presentation of the indications and technic of hip joint disarticulation combined with deep iliac dissection.

More rarely the shoulder girdle (interscapulothoracic amputation) or the buttock and corresponding innominate bone (sacro-iliac disarticulation) must be included in the amputation if the tumor is to be completely removed. Experiences and end-results with 31 cases of interscapulothoracic amputation, in which the entire upper extremity, clavicle, scapula and their muscular attachments are removed *en masse*, were published by Pack, McNeer and Coley<sup>1</sup> in 1942; this report was but the first of a series of investigations on radical girdle amputations in an effort to evaluate these operations for extensive malignant tumors of the extremities. In the current study the comparable operation for the lower limb—sacro-iliac disarticulation—will be considered.

The present report is based on 25 unselected consecutive cases of hip joint disarticulation, five of which were combined with deep iliac dissection, and six cases of amputation through the sacro-iliac joint. These were performed on

the Mixed Tumor Service of the Memorial Hospital from 1926 to 1945, inclusive. All the operations (including 14 additional interscapulothoracic amputations performed subsequent to the published report of 31 cases in 1942) were carried out for malignant tumors of the extremities without a single operative death. Some of the operations were performed for palliative purposes only, since many of the patients harbored extensive and hopelessly advanced cancers. It will be shown that palliation and comfort, and sometimes a cure, may be anticipated by employing these radical but relatively safe surgical procedures.

#### PART I.—HIP JOINT DISARTICULATION

*Historical.*—Amputation through the hip joint is an operation that even now is not undertaken lightly. In the early years of the last century, when sepsis attacked most every wound and anesthesia was unknown, it must have demanded more than ordinary courage for both surgeon and patient. Amputation through the hip joint was first successfully performed by Walter Brachear, of Bardstown, Kentucky, in August, 1806,<sup>2</sup> for a comminuted, compound, multiple fracture of the femur in a 17-year-old mulatto slave boy. A midthigh amputation was carried out, at which time the major vessels were ligated. The bone was then exposed up to the head of the femur on the outer aspect of the thigh and the head of the femur was disarticulated—all of this without anesthesia or antiseptics. Brachear never published an account of his operation.

The earliest recorded instance of a well-conceived surgical amputation through the hip joint was made by Sir Astley Cooper.<sup>3</sup> The operation was performed at Guy's Hospital on January 16, 1824. The patient was a 40-year-old white male whose limb had been amputated just above the knee some years before. The femur had "become diseased from the extremity of the stump to the trochanter major." The actual removal of the limb took 20 minutes, and the ligation of the major vessels and application of a dressing 15 minutes more. The patient became faint during the operation but revived on the administration of wine and admission of fresh air. He bore the operation with extraordinary fortitude. After it was completed, he said to Sir Astley Cooper that it was the hardest day's work he had ever gone through, to which Sir Astley replied that it, too, was almost the hardest he had ever experienced.

The final note on this historic case is as follows: "August, 1825: This patient perfectly recovered, and is now living at the country residence of Sir Astley Cooper."

Many of the early hip joint disarticulations were performed by such famous surgeons as Billroth, Trendelenberg, McBurney, Wyeth, Senn and Halsted.

#### INDICATIONS FOR AMPUTATION THROUGH THE HIP JOINT

Large malignant tumors of the soft somatic tissues of the middle and upper thigh which cannot be completely removed by wide local excision and for which a high thigh amputation cannot assure an adequate margin are best treated by hip joint disarticulation. When the lower extremity is the seat of a bulky, ulcerated, infected, foul-smelling tumor which involves the upper thigh (malignant)

SACRO-ILIAC DISARTICULATION

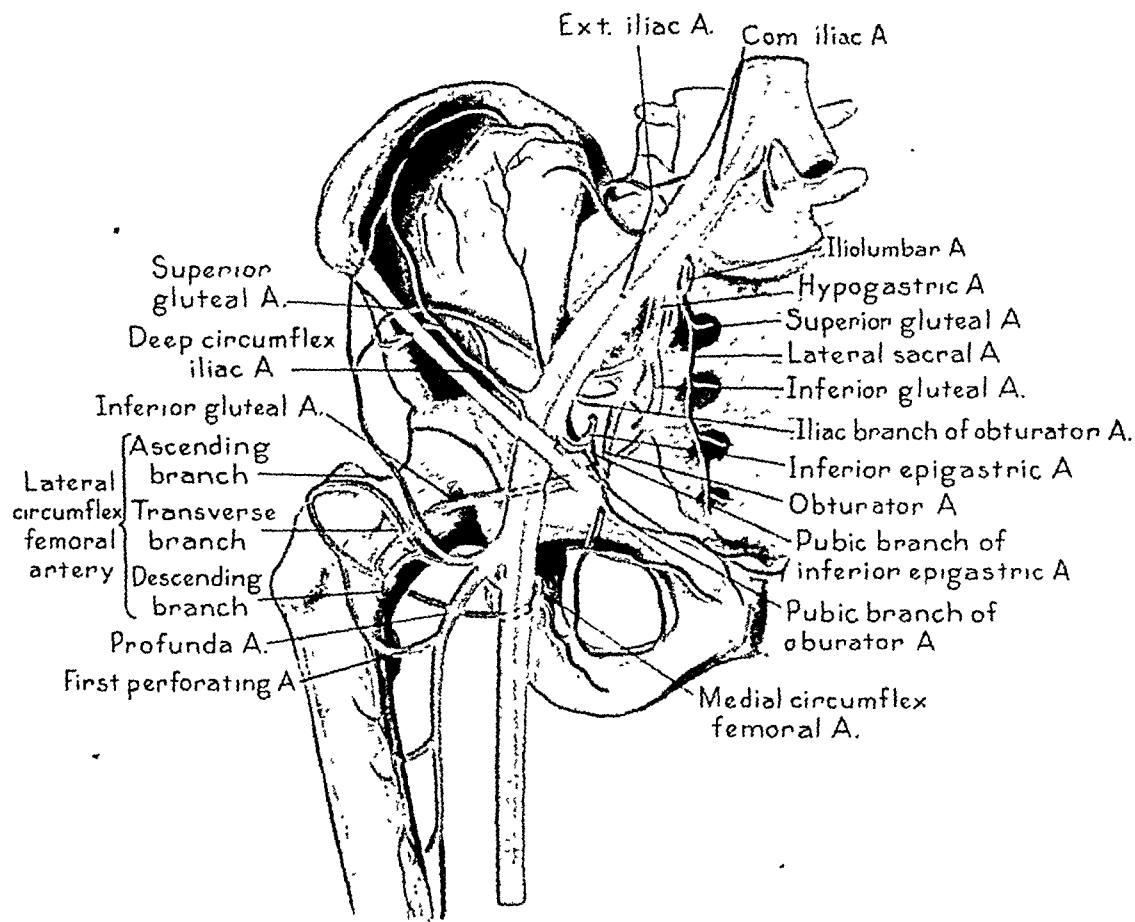


FIG. 1.—Blood supply of the pelvis, showing cruciate anastomosis about hip joint.  
(Redrawn from Morris, Textbook of Anatomy.)

nant lymphoma, Kaposi's hemorrhagic sarcoma, primary malignant tumor with distant metastasis, and metastatic carcinoma) and the patient's general condition has not deteriorated too much, amputation through the hip joint for palliation and comfort is occasionally justified. Elimination of sepsis and pain, conversion to ambulation and partial activity can only be accomplished in hopelessly advanced cases by radical amputation (Figs. 2 and 4). If exarticulation of the hip joint is performed for either a primary operable malignant tumor or for palliative purposes only, it is requisite that the neoplastic process does not extend to or through the hip joint, otherwise nothing less than amputation through the sacro-iliac joint will suffice.



FIG. 2.—Case 20: Bulky, ulcerated, neurogenic sarcoma with lung metastasis on admission. Patient was bedridden and suffered from intense intractable pain. Hip joint disarticulation was performed for palliation. Note café-au-lait spots, characteristic of von Recklinghausen's neurofibromatosis.

For malignant melanoma of the skin of the lower limb where involved inguinal and femoral lymph nodes are far removed from the primary tumor the principle of "excision and dissection in continuity" cannot be applied.\* Under such circumstances only hip joint disarticulation combined with radical groin dissection will accomplish effective removal of the primary tumor, inter-

\**Excision and dissection in continuity* is a term employed to designate radical excision of the primary tumor, intervening lymphatics and all regional lymph nodes by the same encompassing incisions. A wide removal of contiguous skin and an even wider bloc of underlying fascia are included in the dissection. The surgical principle of excision and dissection in continuity is the same one on which the well-established operations for breast and rectal cancer are based, namely, radical removal in continuity of the primary tumor, intervening lymphatic pathways and the regional lymph nodes in one operative seance.<sup>4</sup>

vening lymphatics and all surgically accessible lymph nodes. Such a combination of surgical procedures will be discussed in a separate section of this report.

Malignant tumors of bone and periosteum which occur in the upper and middle femur and for which high thigh amputation cannot assure an adequate margin should be treated by hip joint disarticulation, provided the hip joint and contiguous structures are not involved by tumor. Endothelial myeloma in such a location should be similarly treated if exhaustive studies have demonstrated absence of this disease elsewhere.



FIG. 3.—Surgical specimen in Case 20. Tumor originated in sciatic nerve.

Neoplasms which extend high up on the thigh and which are destined to undergo malignant transformation, such as a huge plexiform neurofibroma (histologically, containing atypical areas) in cases of von Recklinghausen's neurofibromatosis or a bulky osteochondroma (histologically, containing atypical areas) in cases of multiple cartilaginous exostoses are best treated by removal of the extremity through the hip joint, provided they cannot be excised completely by a more conservative operation.

In this series of 25 hip joint disarticulations, seven were performed for spindle cell sarcoma of undetermined histogenesis; four for neurogenic sarcoma; three each for synovioma, chondrosarcoma and melanoma; two for endothelial myeloma, and one each for rhabdomyosarcoma, reticulum cell sarcoma and liposarcoma (Table I). Five of the operations were knowingly performed for palliative purposes only. In retrospect, as a result of this survey, four of these patients should have been subjected to sacro-iliac disarticulation for curative purposes (Fig. 6).



TABLE I  
HIP JOINT DISARTICULATION  
*Clinical and Pathologic Data of the Memorial Hospital Series*

Patient	Age and Sex	Anatomic Diagnosis	Duration of the Tumor	Associated Tumors	Recurrences Prior to Admission	Operation	End-results
1. W. C.	51 M	Neurogenic sarcoma	2 years		3	June 4, 1926	Died suddenly in 6 months, with no evidence of disease
2. B. G.	19 F	Neurogenic sarcoma	5 months	Multiple nevi, neck and ankles	3	Feb 18, 1931	Living without disease 13 years
3. V. M.	59 M	Neurogenic sarcoma	3 months		2	May 25, 1931	Living without disease 13 years
4. D. M.	23 F	Spindle cell sarcoma of undetermined histogenesis	6 months		1	June 24, 1935, Palliative	Died in 6 months
5. M. H.	9 F	Endothelial myeoma	7 months		0	Nov. 6, 1936, Palliative	Died in 5 years
6. L. G.	64 M	Chondrosarcoma	6 months	Primary periosteal sarcoma of 4th left rib	0	Jan. 31, 1937	Died in 2 years
7. B. P.*	46 F	Spindle cell sarcoma of undetermined histogenesis	1 month		2	March 27, 1940	Died in 1 year of other causes
8. F. H.	53 M	Spindle cell sarcoma of undetermined histogenesis	2 months		0	May 8, 1941	Died in 1 year
9. M. E.	43 M	Rhabdomyosarcoma	5 months		2	Sept. 3, 1941	Died in 2 years
10. R. M.*	57 M	Melanoma	2 years		2	Aug. 19, 1941	Died in 2 years
11. M. F.	40 M	Spindle cell sarcoma of undetermined histogenesis	7 months		1	Dec. 5, 1941	Died in 1.5 years
12. H. K.	72 M	Reticulum cell sarcoma	1 year	Eosinophilic granuloma of left tibia	3	May 26, 1942, Palliative	Living without disease 3 years
13. J. C.	46 F	Spindle cell sarcoma of undetermined histogenesis	4 months		1	June 15, 1942	Died in 3 months
14. G. C.	20 M	Synovioma	6 months		0	Aug. 21, 1942	Died in 1 year
15. A. T.	70 F	Chondrosarcoma	8 months		0	Sept. 15, 1942	Died in 1 year
16. G. W.	21 M	Synovioma	1 year		1	Nov. 21, 1942	Died in 8 months
17. M. C.	32 M	Chondrosarcoma	1 year		0	Apr. 9, 1943	Died in 2 months
18. R. C.	39 M	Spindle cell sarcoma of undetermined histogenesis	1 year		1	March 31, 1944	Died in 9 months
19. S. Z.	58 M	Spindle cell sarcoma of undetermined histogenesis	6 months		1	May 9, 1944, Palliative	Died in 6 months
20. D. C.	33 M	Neurogenic sarcoma	4 months	Multiple neurofibromatosis	2	July 3, 1944, Palliative	Died in 5 months
21. W. M.	38 M	Synovioma	1 year		0	Aug. 21, 1944	Died in 4 months
22. R. C.*	38 F	Melanoma	4 years		4	June 18, 1945	Living without disease 9 months
23. S. F.*	62 F	Melanoma	6 months		1	July 6, 1945	Living without disease 9 months
24. D. D.*	15 F	Endothelial myeloma	9 months		2	Oct. 6, 1945	Living without disease 3 months
25. C. H.*	3 M	Liposarcoma	4 months		1	Oct. 25, 1945	Living without disease 3 months

\* Hip joint disarticulation combined with deep iliac dissection.

The youngest patient in this series was 3 years and the oldest 70 years of age.

#### PREOPERATIVE CONSIDERATIONS

The amount of blood which is contained in one of the lower limbs, even after ligation of the common femoral artery, is considerable. Unfortunately no studies on blood loss estimation were made in any of these cases. Despite meticulous hemostasis and minimal apparent blood loss, shock of varying degrees will occasionally occur just as the specimen is being detached from the patient if other precautions for the conservation of blood are not taken. Shock may here be attributed to a sudden decrease in the circulating volume and can be prevented, for the most part, by constant administration of whole blood during the operation. Use of an elastic bandage wrapped around the limb to be amputated is invaluable in conserving circulating blood volume. It should be carefully applied several hours before the operation is planned. An elastic bandage is definitely contraindicated, however, in cases of melanoma where it might possibly aid in the dissemination of tumor cells into the blood stream.

In the event that the tumor is ulcerated and infected, daily local treatment, consisting of gentle débridement, cleansing and antiseptic sprays and frequently applied saline dressings, is of distinct value in reducing the septic condition of the limb. The incidence of postoperative wound infection in this group of cases was decidedly low.

Although vaginal preparation is not as essential as for sacro-iliac disarticulation, the perineal and operative fields can be rendered surgically cleaner by the use of preoperative cleansing douches and antiseptics of the vaginal tube in the operating room, by any of the accepted methods.

A Foley urethral catheter is inserted into the bladder before the patient is taken to the operating room.



FIG. 4.—Case 17: Reticulum cell sarcoma involving entire extremity up to femoral trigone, with no evidence of disseminated disease. The process could not be controlled with radiation therapy. Palliative hip joint disarticulation converted a bedridden septic patient into an ambulatory one. No recurrence or metastasis during past three years.

## ANESTHESIA

Nitrous oxide-ether anesthesia was employed for all cases. In any surgical procedure where a marked drop in blood pressure might occur, spinal anesthesia would not be the anesthetic of choice. Rotation of the patient, which is necessary in exposing the operative field for the posterior dissection, definitely interferes with the technic of spinal anesthesia. In addition, the psychic trauma necessarily induced by a mutilating operation is obviously lessened with the patient asleep. Inhalation anesthesia, be it nitrous oxide-ether or cyclopropane, is to be preferred under the circumstances.

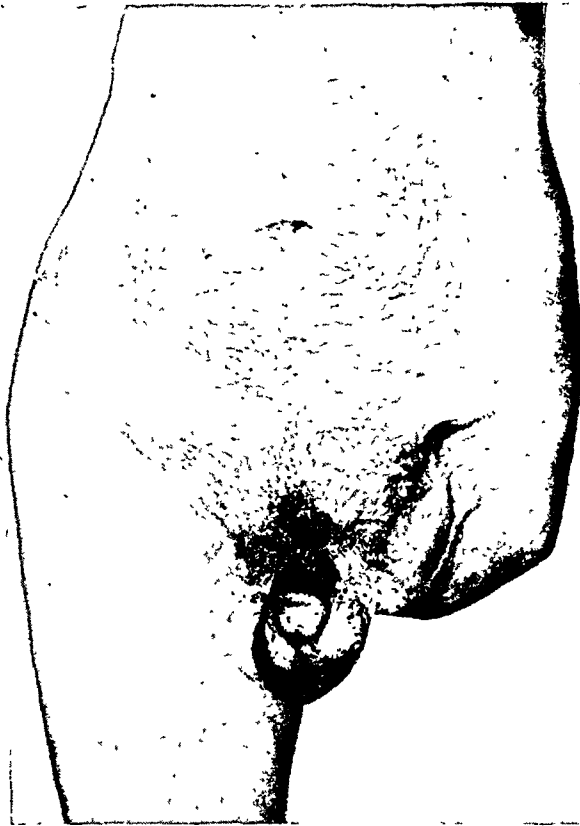


FIG. 5.—Postoperative photograph in Case 17. The absence of an amputation stump following disarticulation of the hip joint makes for prosthetic difficulties. Photograph of prosthesis which is employed in these cases is shown in Figures 12 and 13.

## OPERATIVE TECHNIC

The patient is placed on the table with the affected thigh slightly abducted and externally rotated. In the male the scrotum is temporarily sutured to the opposite thigh, which adequately removes the genitals from the operative field.

An anterior racquet incision is the approach of choice. Obviously the amount of skin to be removed might influence the extent and position of the incision. The upper limit of the incision is placed just above the midportion of Poupart's ligament and continued vertically downward for 4 to 5 cm. The lateral limb of the incision is carried downward and outward across the anterior aspect of the thigh coursing just above the greater trochanter. The medial extension of the incision is similarly carried across the thigh in an opposite direction but at a somewhat higher

level, corresponding to a point several centimeters below the genitocrural fold. These incisions are joined posteriorly below the infragluteal fold. The posterior incision comes to lie transversely across the thigh (Fig. 7).

The apical portion of the incision is deepened through the subcutaneous tissues and fascia reflecting downward a V-shaped flap. The edge of the inguinal ligament is cleared and the neurovascular bundle is exposed. The femoral artery is removed from its sheath, doubly ligated *above the profunda femoris* and cut. The femoral nerve is delivered and severed\* (Fig. 8).

\* All major nerve trunks are freed up, injected with one per cent novocaine and divided. Absolute alcohol is then instilled into the stump, which is ligated relatively high.

The incisions are deepened through subcutaneous tissues and fascia in their entirety. Thick skin flaps are developed, medially to the pubes and laterally well above the greater trochanter. The anterior femoral group of muscles (sartorius and rectus femoris) are cut rather low so that they may be later used to cover the acetabulum. All other muscles are severed as near to their insertion as possible. The limb is then abducted and the median femoral group of muscles (gracilis, pectineus, adductors) are transected. The limb is next adducted; the tensor fascia lata is thus put on a stretch and is severed. The femoral vein is finely ligated and divided.\* The anterior dissection has now been completed (Fig. 9).

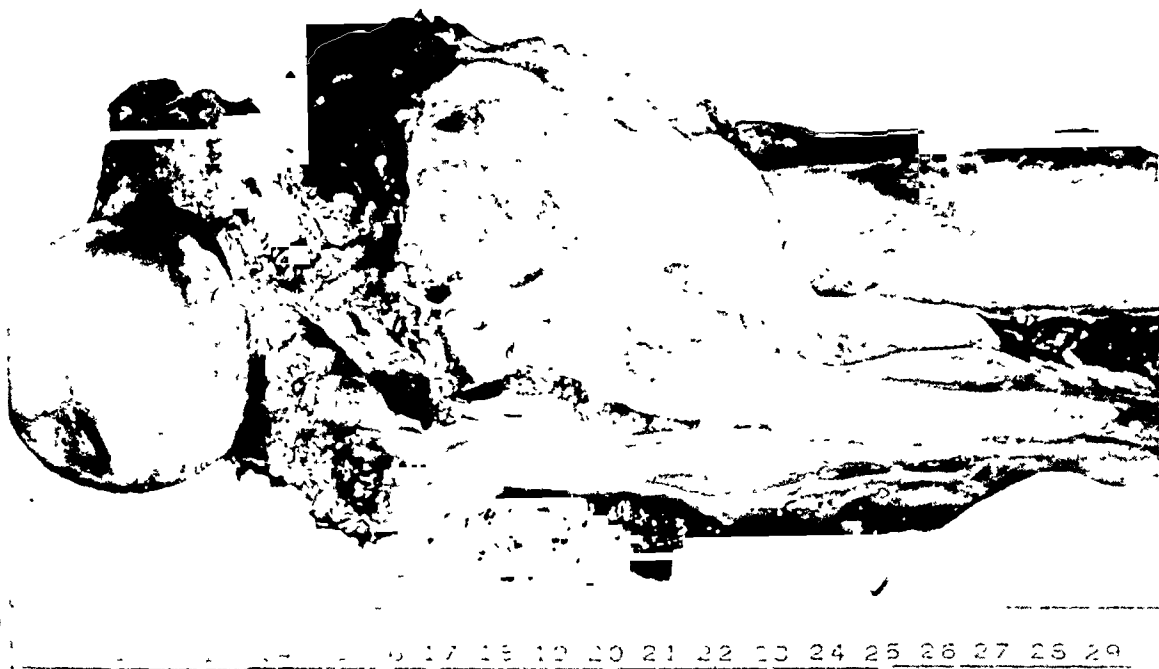


FIG. 6.—An extensive malignant synovioma of the upper thigh which was treated by amputation through the hip joint. Tumor involved tissues contiguous to the hip joint and, in retrospect, this patient should have been subjected to amputation through the sacro-iliac joint.

The limb is again adducted and internally rotated. This maneuver brings the greater trochanter into view so that the muscles which insert into it may be severed (Fig. 10), after which the gluteal muscle group (gluteals, piriformis, obturators, quadratus femoris, gemelli) are cut.

The capsule of the hip joint is exposed and made taut by vigorously adducting and internally rotating the limb. After the capsule of the hip joint is incised, further adduction actually forces the head of the femur out of the acetabulum (surgical dislocation). The round ligament is then severed. The head of the femur is drawn forward and outward. The specimen is now attached to the patient by a posterior pedicle consisting of the hamstring

\* Ligation of the femoral vein is delayed as long as is feasible to allow the limb to drain itself of as much blood as possible.

muscles and sciatic nerves (Fig. 11-A). These are cut across and the specimen is removed.

The excessive muscular and ligamentous tissue is trimmed. The acetabulum is covered by suturing over the previously prepared muscle flap (sartorius and rectus femoris). The skin flaps are approximated, reshaped if necessary and closed. The wound is appropriately drained (Fig. 11-B).

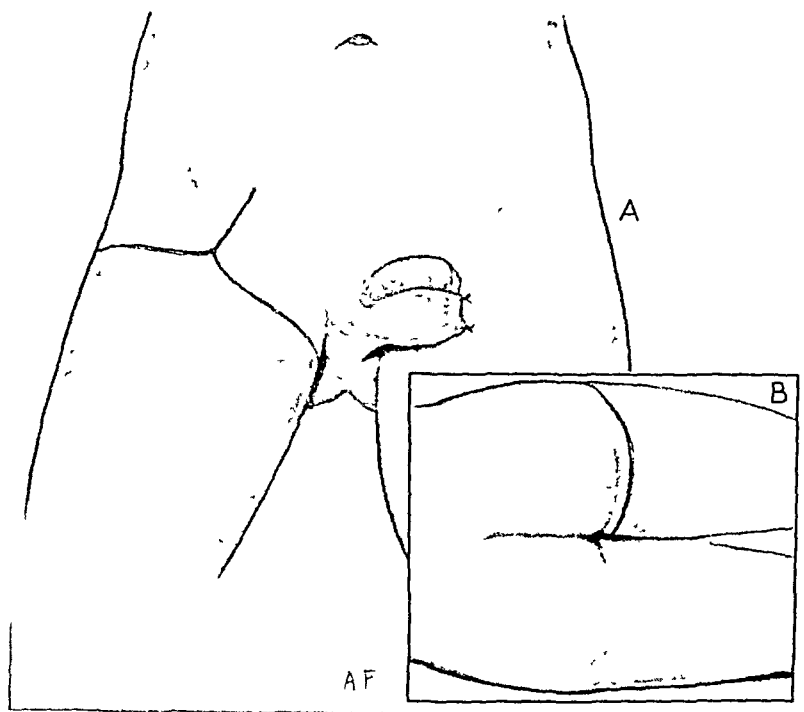


FIG. 7.—(A) Anterior racquet incision for hip joint disarticulation. The upper limit of the incision is placed above the midportion of the inguinal ligament and continued vertically downward for 4 to 5 cm. The lateral limb courses just above the greater trochanter. The medial limb is carried across the thigh at a somewhat higher level, several centimeters below the genitocrural fold.

(B) These incisions are joined posteriorly below the infraglenal fold. The posterior incision comes to lie almost transversely across the thigh.

*Control of Hemorrhage.*—Numerous devices, such as Wyeth's pin, Senn's clamp, and others, and several maneuvers, such as preliminary ligation of the common iliac artery and digital compression of the abdominal aorta have been suggested for the prevention and control of hemorrhage. These are unnecessary. After secure ligation of the common femoral artery, the main blood supply is satisfactorily controlled. Other branches are clamped as cut during the course of the operation. The only major vessel which might produce troublesome bleeding is the obturator artery which is easily secured even after it has been cut.

#### COMPLICATIONS

In general, the course following hip joint disarticulation is relatively smooth and uneventful. Severe shock and hemorrhages were not encountered.

Complications such as anemia, urinary retention and abdominal distention, which not infrequently follow amputation through the sacro-iliac joint, did not occur after amputation through the hip joint. The preoperative use of an elastic bandage, delayed ligation of the common femoral vein, administration of blood during the operation, together with meticulous attention to hemostasis, contributed in no small measure to the notable absence of complications.

The patients were out of bed on the second or third postoperative day. Because of the bulky pressure dressing, a retention catheter was placed in the

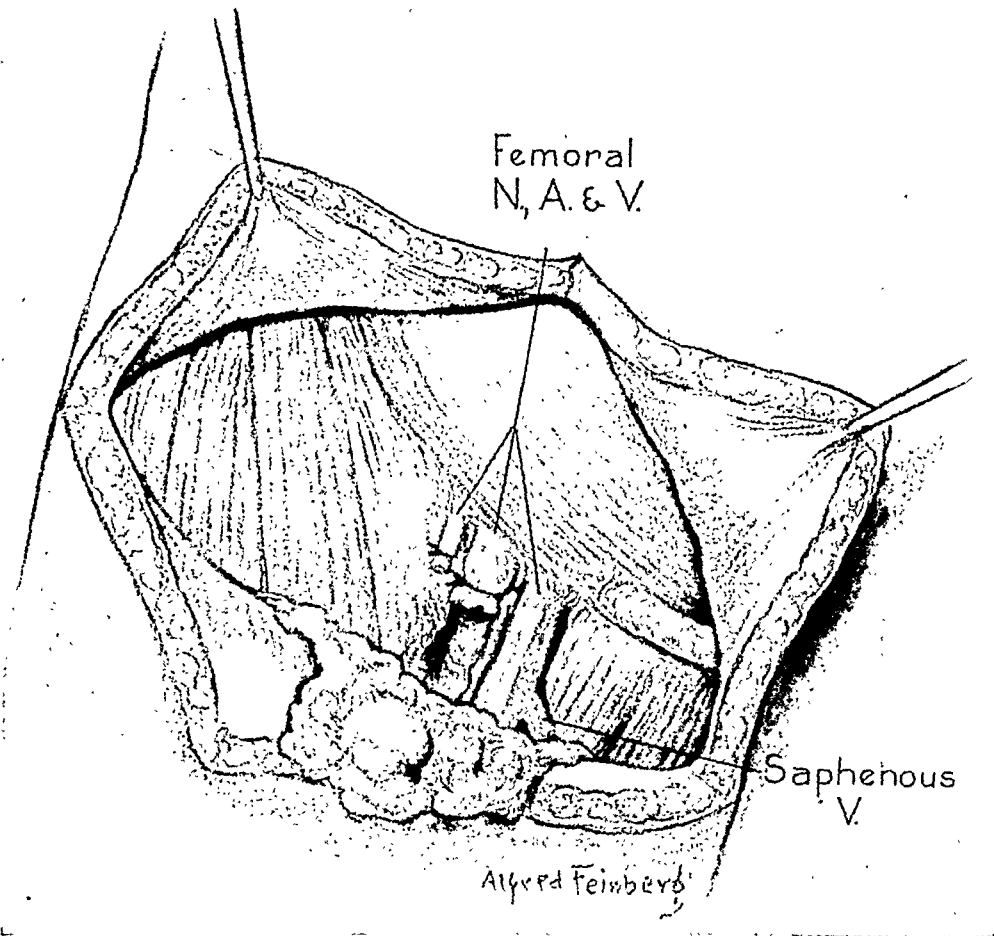


FIG. 8.—The neuromuscular bundle in Scarpa's triangle has been cleared. The femoral artery has been ligated and divided *above its profunda branch*. The femoral nerve has also been transected. Ligation of the femoral vein is delayed as long as is feasible to allow the limb to drain itself of as much blood as possible.

bladder and removed after a lighter dressing was applied (about 48 hours). If the tumor was ulcerated and infected, penicillin was administered for several days postoperatively. If the skin flaps were sufficiently thick and all redundant muscle had been removed from the stump, wound drainage was not prolonged. Drains were shortened on the fifth and removed on the seventh to ninth postoperative days. Frank wound infections were occasionally encountered especially in cases where the tumor was ulcerated and infected and where radical

groin dissection accompanied amputation. In most cases, however, healing occurred *per primam*.

As with amputations elsewhere, stump pain and phantom limb symptoms were not infrequently distressing postoperative complications.

Anemia, which is almost a constant postsurgical manifestation of sacro-iliac disarticulation, did not occur following amputation through the hip joint. The loss of active bone marrow following hip joint disarticulation is not sufficient to interfere significantly with hemopoieses but the amount of additional marrow

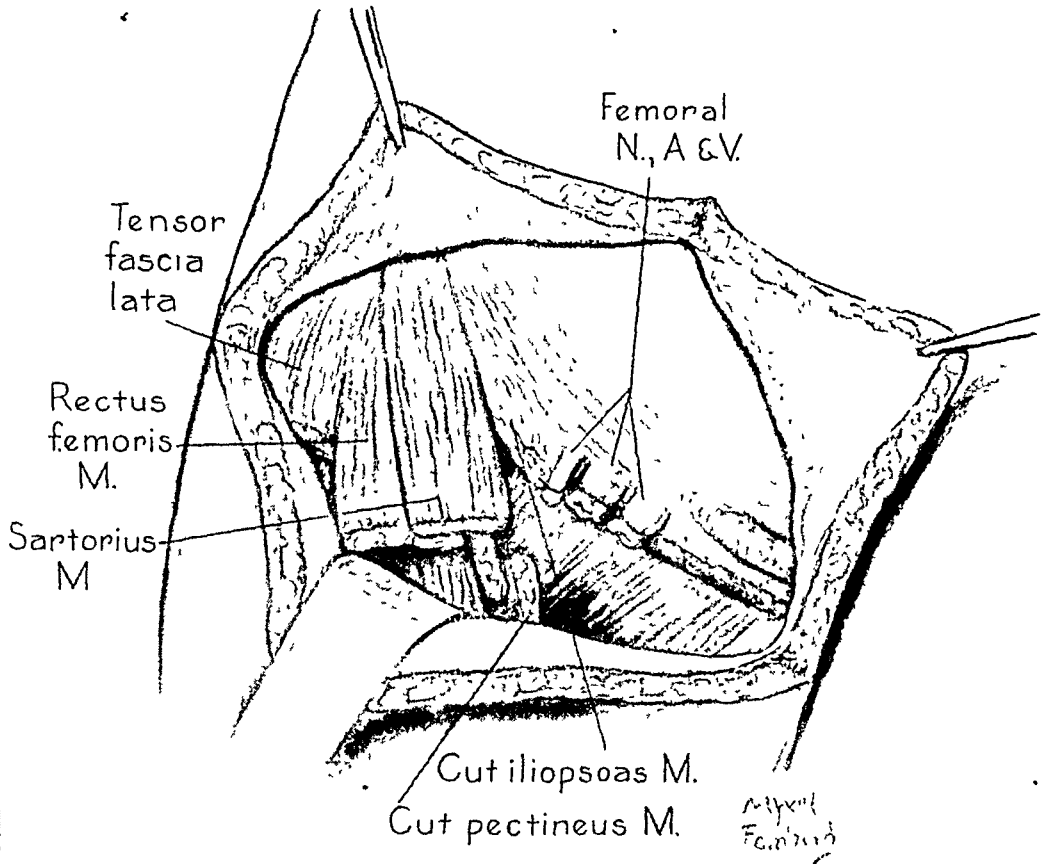


FIG. 9.—The anterior and median femoral muscle groups have been transected. The sartorius and rectus femoris muscles are cut rather low so that they may be later used to cover the acetabulum. The femoral vein is finally ligated and divided, thus, completing the anterior dissection.

contained in the innominate bone might be such that its loss, together with that contained within the long bones of the lower limb, probably results in a resistant but temporary anemia. The anemia which complicates the course of patients subjected to amputation through the sacro-iliac joint will be further discussed in a subsequent section of the present report.

#### PROSTHESIS

The most unsatisfactory feature of amputation through the hip joint has always been the prosthetic difficulties. Since there is no stump to which the

## SACRO-ILIAC DISARTICULATION

prosthesis might be attached, it has been customary to secure it about the girth by means of abdominal straps. Patients have found this awkward, cumbersome, and actually distressing. In most instances they have refused to wear them. We have employed a prosthesis which is hung from the shoulders, in addition to abdominal straps (Figs. 12 and 13), so that not only is it more securely and more comfortably attached but, also, the artificial limb can be swung by the corresponding shoulder making walking distinctly easier. The prosthesis and pelvic attachments weigh ten pounds in all. It is worn no more than one or two hours daily for the first few months as patients find it quite tiring.

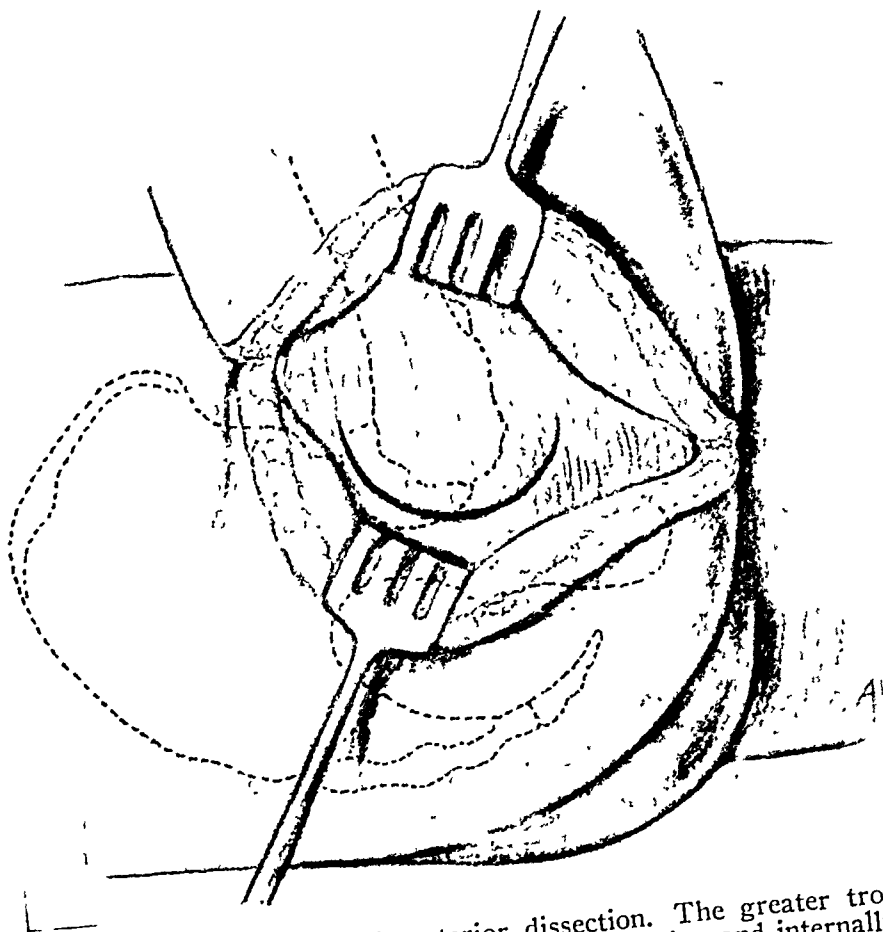


FIG. 10.—Beginning of posterior dissection. The greater trochanter is brought into view by vigorously adducting and internally rotating the extremity. The muscles which insert into it may then be severed.

### PROGNOSIS AND END-RESULTS

The prognosis following amputation through the hip joint will depend on the anatomic type of tumor and its extent, the presence of metastasis and the number and variety of previous surgical procedures (local excisions and conservative amputations).

In the present series of 25 cases of hip joint disarticulation for malignant tumors of all varieties and in all stages of the disease, 16 patients died of local recurrence or metastases, making an over-all salvage rate of 30 per cent (Table I). Five of the operations were knowingly done for palliative purposes only,



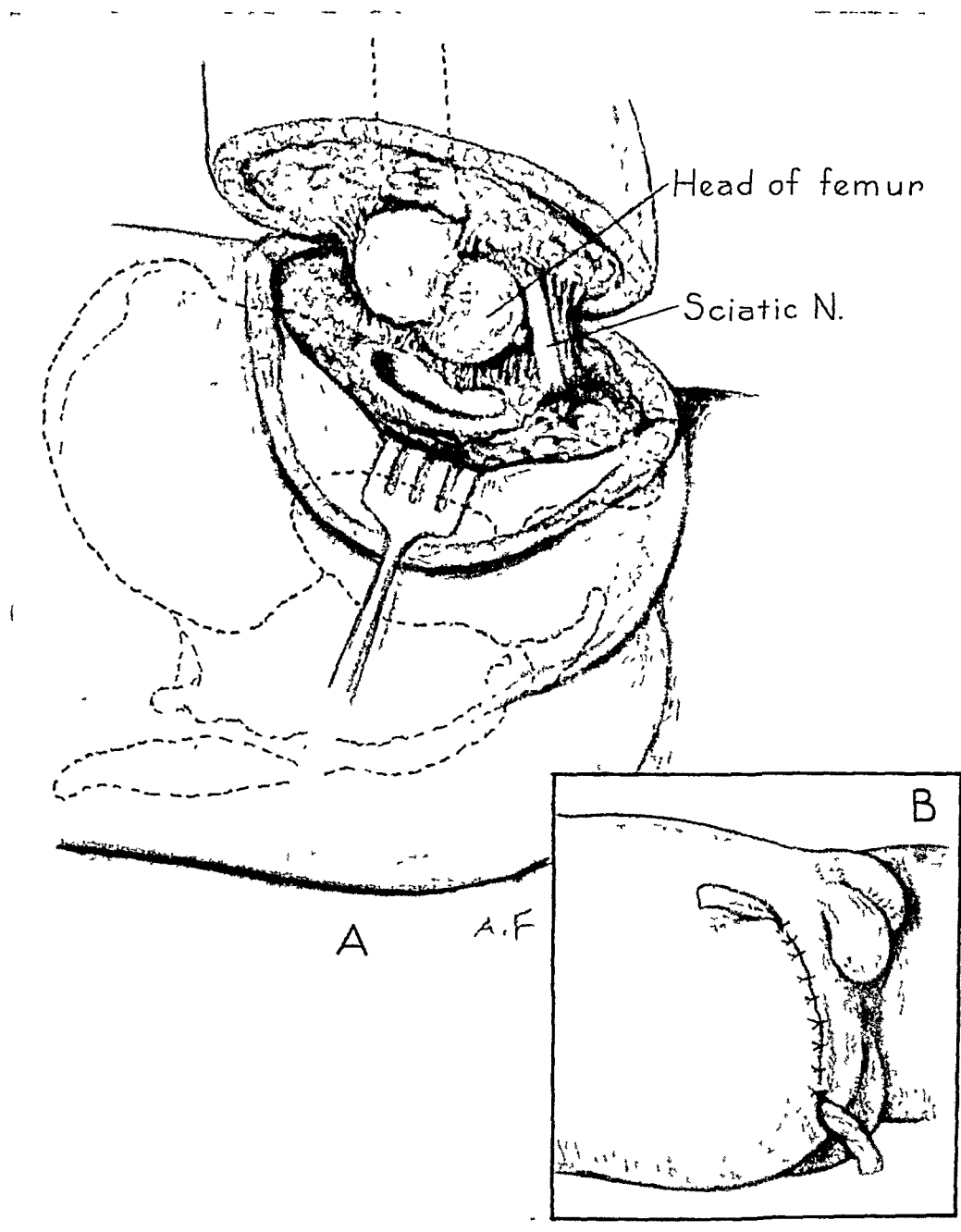


FIG. 11.—(A) Posterior dissection continued. Median femoral group of muscles has been cut. The capsule of the hip joint has been completely incised. By further adducting the limb, the head of the femur is forced out of the acetabulum (surgical dislocation). The round ligament has also been severed. Specimen is now attached to the patient by a posterior pedicle, consisting of sciatic nerves and hamstring muscles.

(B) Wound closure.

## SACRO-ILIAC DISARTICULATION

indicating a net survival rate at the present writing of, 40 per cent. Two patients have remained well for 13 years. In retrospect, four of the patients who had palliative hip joint disarticulations would, at present, be treated by sacro-iliac disarticulation in an attempt to remove the tumor completely. In addition, two of the bone tumor patients would also have been subjected to amputation through the sacro-iliac joint rather than the hip joint in the light of our present knowledge of radical amputations. It is anticipated that such exten-



FIG. 12.—Prosthesis for hip joint disarticulation cases. Note shoulder supports. Pelvic portion is constructed of leather and weighs three pounds. Entire artificial limb weighs ten pounds. This prosthesis may also be employed for cases of hip joint disarticulation combined with deep iliac dissection.

FIG. 13.—Photograph to demonstrate double joint action of prosthesis.

sions of the indications for sacro-iliac disarticulation will eventually raise the net survival rate for both operations.

All but seven of our patients had been subjected to one or more local excisions, and three had undergone conservative amputations prior to the performance of hip joint disarticulation. On admission, all the tumors were bulky and well-advanced. Obviously, these factors unfavorably influence the end-results of the operation. Only when this surgical procedure will be employed in a

selected series of early or moderately advanced previously untreated malignant tumors of the middle or upper thigh will it succeed in appreciably elevating the net survival rate.

The most favorable prognosis was obtained in cases of neurogenic sarcoma, and the most unfavorable in cases of spindle cell sarcoma of undetermined histogenesis. Highly malignant tumors such as synovioma and spindle cell sarcoma are invariably fatal when they are treated by repeated local surgical excisions, no matter how wide. When these tumors occur on the limbs and cannot be completely removed by local excision, primary amputation at an *adequate level* is the patient's only hope for survival. If such a tumor is bulky and situated in the tissues of the middle and upper thigh, nothing less than amputation through the hip joint will suffice. The recent historic dictum "too little and too late" can well be applied to the prevailing conservative attitude of many surgeons toward highly malignant tumors of the soft somatic tissues of the limbs and is to be condemned.

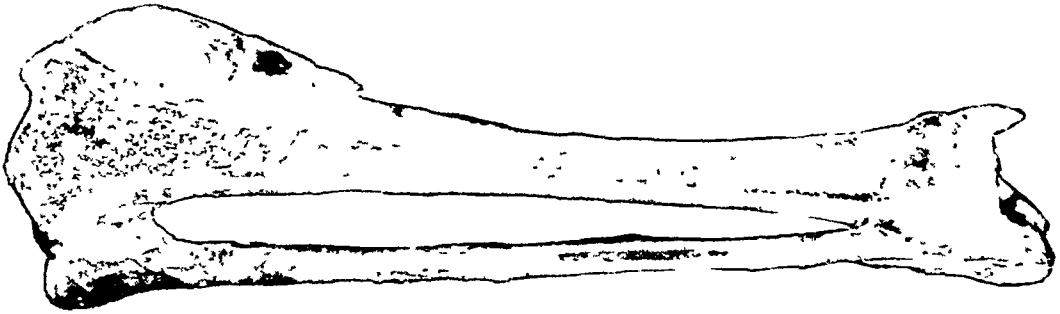


FIG. 14.—Endothelial myeloma of tibia which invaded the soft tissues of the upper leg. A metastasis was also present in the popliteal space. Since the inguinal nodes were involved (proven by aspiration biopsy), hip joint disarticulation combined with deep iliac dissection was performed.

#### PART II.—HIP JOINT DISARTICULATION COMBINED WITH DEEP ILIAC DISSECTION SURGICAL PRINCIPLES AND INDICATIONS

In the treatment of melanoma of the extremities with demonstrable involvement of the regional lymph nodes, the principle of excision and dissection in continuity should be practiced whenever possible. If the primary tumor is located too far from the first relay of lymph node metastasis, this surgical principle cannot, of course, be employed. In such cases wide surgical excision of the primary lesion subsequently followed by a separate dissection of the regional lymph nodes will only very rarely succeed in removing the intervening lymphatic pathways between the primary tumor and the involved regional lymph nodes making local recurrence or distant metastasis almost inevitable. This conclusion has been reached after many years of surgical experience with over 900 cases of melanoma. In those cases, therefore, where it is technically impossible to excise the primary tumor with sufficient width, together with the intervening lymphatics and involved regional lymph nodes by excision and dissection in continuity, exarticulation of the limb together with removal of the

## SACRO-ILIAC DISARTICULATION

lymphatic contents of the regional node-bearing space (groin and retroperitoneal space, axilla, *etc.*) is indicated—interscapulothoracic amputation and supraclavicular dissection for the upper extremities and hip joint disarticulation combined with deep iliac dissection for the lower limb.

The operation of interscapulothoracic amputation is ideal for those cases of melanoma of the upper extremity where excision and dissection in continuity cannot be utilized. By employing interscapulothoracic amputation the entire axilla is *excised* rather than entered and dissected, so that all regional

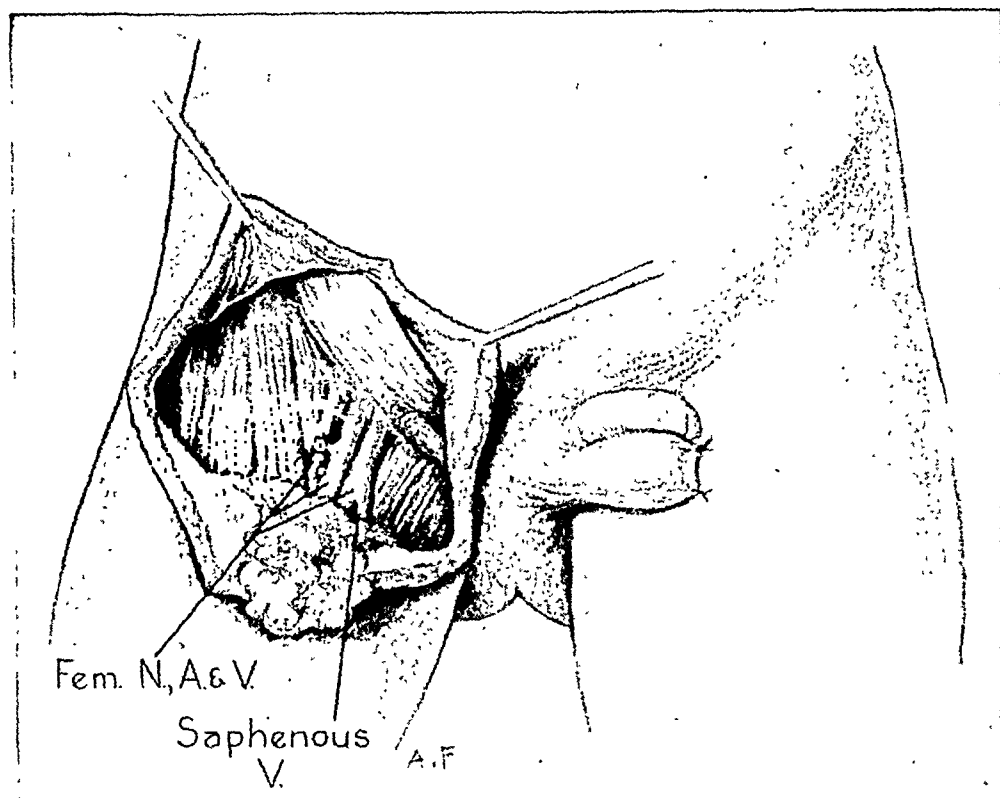


FIG. 15.—Hip joint disarticulation combined with deep iliac dissection. After development of anterior flaps, the lower anterior abdominal wall, inguinal ligament, inguinal canal and Scarpa's triangle are cleared of all fascial, fatty, areolar and lymphatic tissues; this bulk of tissue is dissected downward and is left attached to the specimen. The femoral vessels and nerve may be seen exposed and cleared. First stage of groin dissection completed.

lymph nodes are adequately encompassed and removed *en bloc* without apparently transecting any of the pertinent major lymphatic chains.

We believe that the concept of treating melanoma and metastasizing epitheliomas of the extremities together with the involved regional lymph nodes by excision and dissection in continuity, interscapulothoracic amputation (with neck dissection if necessary) or hip joint disarticulation combined with deep iliac dissection, depending on the anatomic factors which are present, to be surgically sound and to offer the patient his best chance for survival. Radical amputation (disarticulation), including excision of metastatic regional lymph nodes *en bloc*, for selected cases of melanoma is now being employed on the Mixed Tumor Service of the Memorial Hospital. Only after an appreciable number of such operations have been performed as the initial treatment in a

selected group of previously untreated patients and followed postoperatively for an adequate period can these surgical procedures be accurately and finally evaluated.

Other highly malignant neoplasms may not infrequently metastasize to the regional lymph nodes such as spindle cell sarcoma, synoviuma and endothelial myeloma. The same surgical principles should be applied in their management as for melanoma (Fig. 14).

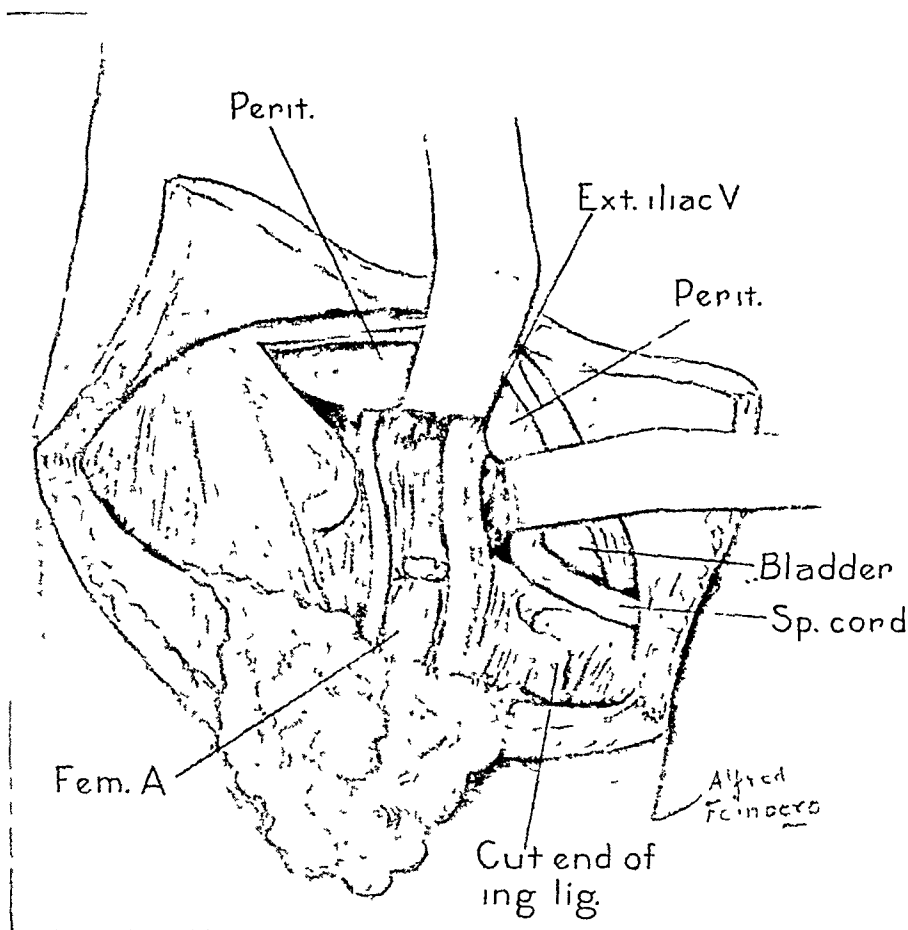


FIG. 16—The inguinal ligament has been severed. Peritoneum and bladder are retracted upward and medially, exposing the retroperitoneal space and its contents. (In this illustration the deep epigastric vessels have been ligated and divided.) Lymph nodes and fatty, areolar tissue accompanying the external iliac vessels are dissected from above downward. The femoral artery is ligated and divided *above its profunda branch*. This completes the deep iliac dissection (second stage of radical groin dissection) and hip joint amputation may now be proceeded with in the usual manner. Note that ligation and division of the femoral vein is delayed to allow the limb to empty itself of as much blood as possible.

#### OPERATIVE TECHNIC

The preoperative preparation, anesthesia and other considerations are the same as for amputation through the hip joint. Bladder catheterization should always be done. Since this combined operation is most often performed for melanoma, an elastic bandage is not usually applied, for it might possibly

disseminate tumor cells into the blood stream. The technic of radical groin dissection, as described by Pack and Rekers,<sup>5</sup> is employed, but is altered by omitting the dissection of the upper thigh and Hunter's canal. With this combined operation, a deep iliac dissection is performed and the groin space is actually *excised* rather than dissected, a particularly desirable procedure for the removal of a regional lymphatic basin which contains melanoma.

An anterior racquet incision is made as for hip joint disarticulation but is so modified that the upper extremity of the incision is placed 4 to 5 cm. above and 3 to 4 cm. medial to the anterior superior iliac spine. The apex of the incision lies above the junction of the outer and middle thirds of Poupart's ligament. The anterior portions of the medial and lateral flaps are developed. The skin edges are defined by the scalpel and towels are applied to the wound edges by means of numerous tenacula. These tenacula are very helpful in facilitating subsequent dissection of fat and fascia from the skin because when dealing with melanoma it is important to make the flaps thin. With the tenacula elevated, the subcutaneous fat is dissected widely until the inguinal region and lower abdominal wall over the iliac area have been denuded. The lower flap, roughly shaped like an inverted "V," is reflected downward and need not necessarily be thin as it is part of the surgical specimen. Dissection is started from above downward, removing fascia, fat and lymphatic tissue *en bloc*. The inguinal canal and femoral vessels are exposed and cleared. This bulk of tissue is reflected downward and left attached to the specimen. The first stage of the groin dissection has now been completed (Fig. 15).

The edge of the inguinal ligament is split in its middle. The cut ends of the ligament are retracted and the retroperitoneal space is entered. The deep epigastric artery is frequently not preserved. The peritoneum and abdominal viscera are retracted upward and medially, using deep retractors. Care must be taken at this point not to open the peritoneum or to injure the urinary bladder. This maneuver exposes the iliac vessels and retroperitoneal lymphatic tissues. If necessary, the external oblique and transversalis muscles and fascia can be incised vertically upward, exposing the retroperitoneal space and its contents well beyond the bifurcation of the aorta. The chain of lymph nodes, fat and areolar tissue along the external iliac vessels are dissected from above downward, including those overlying the obturator foramen, and removed *en bloc*. On completion of this deep iliac or second stage of groin dissection, the common femoral artery is doubly ligated and divided *above the profunda femoris*, the outlined incisions are deepened through subcutaneous tissue and fascia in their entirety and the operation of hip joint disarticulation is carried out in the usual manner (Fig. 16).

The wound closure will vary with the amount of skin which has been removed. In most cases the suture line of the approximated skin flaps will be situated on the lateral aspect of the pelvis and stump and will turn medially along the stump toward the perineum. A stab wound is made in the large medial flap, which overlies the lower half of the anterior abdominal wall, through which the wound is drained. A drain is also allowed to emerge through

the most dependent portion of the sutured incision. Because of the extensive thin flaps which have been developed, it is essential that a bulky pressure dressing be applied. These skin flaps, like skin grafts, must be maintained snugly and uniformly against the underlying tissue bed. The pressure dressing should be firm enough to prevent pocketing of serum but not too firm, otherwise necrosis of the flaps will occur.

#### COMPLICATIONS AND CLINICAL COURSE

The postoperative course, like that following straight amputation through the hip joint, is essentially uneventful except for wound complications. The utilization of extensive and very thin skin flaps with an impoverished blood supply invariably produced a certain amount of skin necrosis along the wound margins, resulting in infections. The inevitable lymphorrhea and pocketing of serum beneath the flaps also encourage infections and contribute to delayed healing.

Meticulous wound care, which should include repeated aspirations through the flaps of accumulated serum and liquefied fat together with the use of a judiciously applied pressure dressing, is an essential feature in the post-surgical management of these cases. The skin margins of the wound usually survive from four to eight days before necrosis becomes manifest and demarcation of the dead skin is established. It is well to wait until the necrosis is fairly complete before proceeding with débridement. As with cases of straight radical groin dissection, patients with appreciable skin defects will require grafting, especially if previous radiation therapy has been given to the area. By administering adequate amounts of penicillin postoperatively and grafting large defects early, the convalescence of patients may be shortened considerably.

The problems of prosthesis are similar to those following straight hip joint disarticulation. Apparently the additional procedure of radical groin dissection does not add to the difficulties. The shoulder type of artificial limb is also prescribed in these cases.

#### PROGNOSIS AND END-RESULTS

In the series of 25 hip joint disarticulations here reported five of the operations were accompanied by deep iliac dissection, an incidence of 20 per cent. Three were performed for melanoma, one for Ewing's endothelial myeloma and one for synovioma. One of the melanoma patients died two years after operation of lung metastasis and one of the patients with synovioma succumbed to massive local recurrence and lung metastasis six months after operation. The other patients are alive and well at the present writing, with no evidence of recurrence or distant metastasis. In retrospect, one of the patients with synovioma should have been subjected to sacro-iliac disarticulation because the bulky mass involved the capsule of the hip joint (Fig. 6).

Our cases are too few at present on which to base a comprehensive discussion of prognosis and end-results for this combination of surgical procedures. However, when melanoma, usually recurrent and frequently associated with satellite tumors, or a comparably highly malignant neoplasm is encountered in

the distal portion of an extremity and the regional lymph nodes are demonstrably involved (positive biopsy), that limb is condemned, for excision and dissection in continuity of the primary tumor, regional lymph nodes and intervening lymphatics is technically impossible. Furthermore, wide local excision of the melanoma followed later by radical dissection of the regional lymphatic basin (groin, axilla, neck) has proven to be inadequate in an experience covering more than 900 cases of melanoma. In order, therefore, to remove the gross limitations of the disease with success, exarticulation of the limb together with excision of the regional lymph nodes (hip joint disarticulation combined with deep iliac dissection, interscapulothoracic amputation with or without neck dissection) must be resorted to if the prognosis and end-results for melanoma and comparable tumors on the extremities with involved regional lymph nodes are to be improved. Most surgeons do not hesitate to amputate radically for osteogenic sarcoma. Is not radical amputation (disarticulation) justified for neoplasms of similar anatomic and clinical behavior if they cannot be adequately removed by a more conservative procedure?

*(To be continued)*

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# CHEST WOUNDS IN BATTLE CASUALTIES

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THIS REPORT is concerned with 206 battle wounds involving the thoracic cavity. This group of cases was treated during the period of 24, October, 1944 to 1, March, 1945. A similar group of cases treated between 1, July, 1944 and 24, October, 1944 has been reported previously.<sup>1</sup> Wounds of the chest cavity are classified under four headings which will be discussed separately.

## PENETRATING WOUNDS—NOT REQUIRING THORACOTOMY

Eighty-seven casualties had relatively minor wounds involving the chest cavity and required no treatment other than aspiration and débridement of the chest wall wounds. In some, the wounds were so slight as to require only dressings. Three patients classified in this group had hemopneumothorax of such extent that it was felt that aspiration alone would not be adequate; these were treated by closed tube suction drainage. Thoracotomy did not become necessary in any of these cases.

There was one death in this group. The death occurred in a soldier admitted to the hospital with a clostridial infection in a compound fracture of the radius and ulna, in addition to a penetrating chest wound. The arm was amputated and the wound of the chest wall débrided. Death was thought to be caused primarily by the toxemia of the clostridial infection although autopsy revealed extensive intrapulmonary hemorrhage.

## PENETRATING WOUNDS—REQUIRING THORACOTOMY

Forty-six patients with penetrating wounds of the chest cavity were subjected to thoracotomy. There were four deaths, a mortality of 8.7 per cent.

At times, it is difficult to decide which patients with penetrating wounds of the chest cavity require thoracotomy. With increasing experience, our tendency has been to be more conservative. In the first group of 87 patients,<sup>1</sup> 42, or 47 per cent, were subjected to thoracotomy, while in the second group of 133 patients, 46, or 34 per cent, were treated by thoracotomy. Minor lung lacerations heal well without suture,<sup>2</sup> and the collection of fluid and air in the pleural cavity can be controlled by repeated aspirations or closed tube drainage. Under the following conditions, it has been our policy to perform a limited thoracotomy through the wound of entrance, or, in some cases, through the wound of exit: (1) When the skin incision necessary for débridement of the chest wall wound caused sucking. (2) When there was extensive damage to the chest wall and roentgenographic evidence suggested severe lung damage. (3) In the presence of progressive bleeding. (4) When large, easily removable foreign bodies were present.

There were four deaths in the group of thoracotomies performed for penetrating wounds of the chest. Three appear to have been due primarily to the amount of lung damage sustained. The fourth death occurred in a patient oper-

# CHEST WOUNDS IN BATTLE CASUALTIES

ated upon because of a suspected heart injury. A summary of these deaths follows:

TABLE I

## WOUNDS OF THE CHEST CAVITY

1, July to 24, October, 1944—24, October, 1944 to 1, March, 1945

	GROUP 1			GROUP 2			TOTALS		
	Previously Reported <sup>1</sup>			Current Series					
	No.	Deaths	Mortality	No.	Deaths	Mortality	No.	Deaths	Mortality
Penetrating wounds not requiring thoracotomy	45	1	2.2%	87	1	1.1%	132	2	1.4%
Penetrating wounds requiring thoracotomy	42	2	4.7%	46	4	8.7%	88	6	6.8%
Sucking wounds	32	11	34.3%	35	4	11.4%	67	15	22.7%
Thoraco-abdominal wounds	36	11	30.5%	38	8	21.0%	74	19	27.0%
Totals	155	25	16.1%	206	17	8.2%	361	42	11.5%

Note: Two cases originally reported are not included in Group 1. One was a patient with a tension pneumothorax primarily treated in a Field Hospital, the second was a patient with a crush injury of the chest.

TABLE II

## CAUSES OF DEATH FOR COMBINED SERIES

Penetrating wounds—No thoracotomy	2
Intrapleural hemorrhage	1
Gas gangrene of arm	1
Penetrating wounds—Thoracotomy	6
Cardiac failure—during operation	1
Cardiac hemorrhage—during operation	1
Shock	1
Intrapulmonary hemorrhage	1
Pulmonary edema	1
Pleural effusion	1
Sucking wounds	15
Pneumonia	5
Shock	5
Intrapulmonary hemorrhage	3
Respiratory failure—mechanical	2
Congenital diaphragmatic hernia	1
Fracture of sternum	1
Thoraco-abdominal wounds	19
Peritonitis	6
Shock	5
Pneumonia	3
Renal failure	1
Cardiac tamponade	1
Anesthetic	1
Intracranial injury	1
Pancreatic fistula	1

(1) The first death occurred in a soldier with a compound fracture of the right scapula, compound fractures of the second, third and fourth ribs, and a moderately severe laceration of the lung. The chest was explored through the seventh interspace, the blood was aspirated, and a laceration of the lung sutured. This patient died on the third postoperative day of shock and bronchitis.

(2) The second death occurred in a soldier with a penetrating wound of the left shoulder and chest cavity. There were fractures of the fifth and sixth ribs and a partial transection of the spinal cord at the level of the ninth dorsal vertebra. A limited thoracotomy was performed through the wound of entry,

and a severely lacerated lung sutured. This patient died on the second post-operative day. Death was apparently caused by pulmonary edema.

(3) The third death occurred in a soldier with an extensive wound of the chest and fractures of the eighth and ninth ribs. The lung was found to be adherent to the chest wall and so badly lacerated that an adequate suture was not possible. After suture of the chest wound, closed tube drainage was instituted. The patient died on the first postoperative day of intrapulmonary hemorrhage and shock.

(4) The fourth death occurred in a prisoner of war who had a compound fracture of the humerus and a penetrating wound of the chest cavity. This patient did not improve under treatment in the Shock Ward and thoracotomy was undertaken because it was thought that his symptoms might be due to a cardiac tamponade. At operation, no heart injury was found. The arm was immobilized in a plaster spica after débridement of the wound. This patient died on the seventh postoperative day of progressive respiratory failure. Aspiration of the chest had been unsatisfactory due to the presence of the plaster spica, and a large pleural effusion was an important factor in causing death.

#### SUCKING WOUNDS

Thirty-five sucking wounds of the chest were treated with four deaths, a mortality of 11.4 per cent. These wounds were treated by a débridement which included a resection of the fractured rib ends. The wounds were enlarged enough to allow exploration of the chest cavity and removal of blood clots and foreign bodies. Lacerations of the lung, when present, were sutured. All layers of the chest wall including skin were sutured. The four deaths in this group were caused primarily by shock, the result of blood loss, and disturbed respiratory mechanics. A summary of the four deaths follows:

(1) The first death occurred in a prisoner of war with a sucking wound of the left chest, a laceration of the pericardium and a large hematoma of the lung. Death on the first postoperative day was due to shock.

(2) The second death occurred in a soldier with a sucking wound of the left chest and a wound of the right knee. The blood loss had been large due to lacerations of the internal mammary and popliteal arteries. After what was felt to be adequate blood replacement, the patient was taken to the operating room where he died of shock during the operation.

(3) The third death occurred in a soldier who was admitted, in a state of unconsciousness, with a large sucking wound of the right chest. He showed little response to shock treatment and for this reason the wound was simply débrided and closed, under local (novocaine) anesthesia. This patient died on the second postoperative day without ever fully regaining consciousness.

(4) The fourth death occurred in a soldier with a large sucking wound of the right chest in the posterior axillary line. This patient also was unconscious on admission and did not respond to shock treatment. The wound was closed without anesthesia, but the patient failed to improve, and died on the first post-operative day. This and the preceding case are probably examples of "irreversible shock."

THORACO-ABDOMINAL WOUNDS

Thirty-eight patients were operated upon for thoraco-abdominal wounds. Twenty-two of the wounds were in the right chest and 16 in the left. There were eight deaths, a mortality of 21 per cent. Some of the patients in this group had relatively minor injuries in spite of the fact that the wounding missile had passed into or through both the chest and the abdominal cavities. The surgical approach to these patients depended on whether the major injury was thought to be in the chest or in the abdomen. A wound of the chest which was sucking was always treated before the abdominal injury, and in many cases, it was found that adequate exploration and reparative surgery of the upper abdomen could be done through the diaphragm. In our experience, this was the easiest route through which to remove a spleen. In other cases, where the major injury was obviously in the abdomen, a celiotomy incision was made and a thoracotomy avoided if possible. In wounds of the left chest, the diaphragm was routinely sutured, but we did not always suture the right diaphragm if this procedure required a thoracotomy in addition to the celiotomy.

There were eight deaths in this group; four were due to chest complications, three succumbed to the abdominal injury, and one died from shock. A summary of these cases follows:

(1) The first death occurred in a soldier with a perforating wound of the left elbow, a fracture of the lower end of the humerus, fractures of the 11th and 12th ribs, a laceration of the diaphragm and lacerations of the spleen and stomach. The stomach and diaphragm were sutured but, as the spleen had stopped bleeding, it was not removed. The arm was debrided and placed in a plaster encasement. Death on the third postoperative day was due to pneumonia.

(2) The second death occurred in a soldier with a perforating wound of both chest cavities. The left chest wound was sucking and there were lacerations of the diaphragm and liver, a contusion of the heart, and fractures of the costal cartilages near the sternum. Death occurred on the operating table and was apparently due to shock.

(3) The third death occurred in a soldier with a perforating wound of the right chest through the tenth rib. The diaphragm, liver and kidney were lacerated. The liver was sutured and the kidney packed to control bleeding. Death was caused by pneumonia.

(4) The fourth death occurred in a soldier with a perforating wound of the right chest and lacerations of the diaphragm and liver. The liver was sutured to control bleeding. Death was due to peritonitis and pneumonia.

(5) The fifth death occurred in a soldier with a sucking wound of the left chest and abdomen. The missile entered between the eighth and ninth ribs and lacerated the lung, diaphragm, spleen, stomach and liver. The stomach, spleen and diaphragm were sutured after enlarging the wound of entrance. This patient died on the second postoperative day of respiratory failure. At autopsy, a bilateral pneumothorax was found. There was no wound of the right chest and no satisfactory explanation for the right pneumothorax was discovered.

(6) The sixth death occurred in a soldier with a wound of the right chest

and abdomen. The diaphragm, liver, kidney and colon were lacerated. The kidney was removed, the diaphragm sutured and a loop-colostomy made of the injured colon. The cause of death was bronchopneumonia and pulmonary edema.

(7) The seventh death occurred in a soldier with a wound through the left upper abdomen which injured the spleen, kidney and pancreas. It was not recognized that the missile had entered the pleural cavity. The spleen was removed,



FIG. 1



FIG. 2

FIGS. 1 and 2.—Roentgenograms showing a large shell fragment penetrating the left chest and lung. This patient had minimal respiratory distress on admission to the hospital and was not in shock. Upon removal of the shell fragment, there was brisk bleeding from a branch of the bronchial artery. This was ligated, the laceration of the lung sutured and the chest closed without drainage. The patient made a good recovery.

but nothing was done to the kidney or pancreas since both had stopped bleeding. An empyema developed and was drained. The patient subsequently developed a large fluctuating mass in his left flank. An incision was made from which a large amount of clear fluid drained. At autopsy, it was found that the drainage came from fistulae of both the kidney and pancreas. Profuse drainage followed, and it is probable that the pancreatic fistula was the primary cause of death.

(8) The eighth death occurred in a soldier with a thoraco-abdominal wound of the left side. The chest wound was sucking and the diaphragm, spleen, jejunum and colon were lacerated. The sucking wound was closed and a celiotomy incision made. The spleen was removed, the diaphragm and the perforation of the jejunum sutured and a loop-colostomy made of the injured colon. An empyema developed and was drained. Later, an intra-abdominal abscess

## CHEST WOUNDS IN BATTLE CASUALTIES

developed and this was also drained. The patient died one month after injury from intra-abdominal and retroperitoneal infection.

### INFECTION

There were no infections of the pleural cavity in the group of 157 cases first reported,<sup>1</sup> but six empyemas developed in the second group of 206 cases. The reason for this is not clear for the surgical treatment, and the use of penicillin and sulfadiazine remained essentially the same. Four empyemas developed in patients with thoraco-abdominal wounds, one followed the closure of a sucking wound of the chest, and one followed thoracotomy upon a patient with a penetrating chest wound. There were no known infections in those patients treated by simple débridement and aspiration.

### RESULTS

In the 87 penetrating wounds not requiring thoracotomy there was only one death, a mortality of 1.1 per cent (Table I). The penetrating wounds requiring thoracotomy show a mortality of four in 46 cases, or 8.7 per cent. In 35 sucking wounds, there were four deaths, an 11.4 per cent mortality. Eight of the 38 thoraco-abdominal cases died, a mortality of 21 per cent. It will be observed (Table I) that the total mortality in this series is approximately half that of the previous series.

In the two series combined, there is a total of 361 thoracic cases, representing 3.6 per cent of the 10,700 battle casualties treated in the Second Evacuation Hospital between 1, July, 1944 and 1, March, 1945. The total mortality for the combined series of 361 cases was 42, or 11.5 per cent. The 12 casualties with chest wounds who died in the shock ward before operation are not included in these figures.

### CONCLUSIONS

The following conclusions are based upon the total experience to date:

1. Small penetrating wounds of the chest cavity are best treated by aspiration alone.
2. Penetrating wounds of the chest cavity require a limited thoracotomy:
  1. When the skin incision necessary for débridement of the chest wall wound causes sucking.
  2. When there is extensive damage to the chest wall and roentgenographic evidence suggests severe lung damage.
  3. In the presence of progressive bleeding.
  4. When large easily removable foreign bodies are present.
3. In treating sucking wounds of the chest, the wound should be enlarged enough to allow suture of a laceration of the lung, removal of foreign bodies, and evacuation of blood clots as well as a complete débridement of the chest wall wound.
4. Many thoraco-abdominal wounds can be dealt with through a thoracotomy incision alone. In others, the major injury is in the lower abdomen and these patients require celiotomy after treatment of the chest wound.

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# THORACO-ABDOMINAL WOUNDS WITHOUT ABDOMINAL SIGNS

## REPORT OF TWO CASES

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AND

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THE OPERATIVE TREATMENT of the thoraco-abdominal war wound in the forward echelon hospital poses a difficult problem in judgment because, as DeBakey has pointed out, if either the chest or the abdomen may be attacked primarily, the patient's chances of recovery are very much better than if both must be attacked separately at a single sitting. DeBakey and Carter point out that, in any chest wound, thorough roentgenologic and fluoroscopic examination of the chest and abdomen must be carried out because, in a surprising number, the missile will be found to have entered the abdomen. A recent report of an Evacuation Hospital in the North African Theater shows that 8 per cent of all chest wounds involved the abdomen as well.

The two cases to be presented have three characteristics in common and it is this fact, as well as their unusual nature, that has led to their being reported. First, both presented left-sided thoraco-abdominal wounds involving the stomach, with a generous spillage of gastric contents into the thorax. Second, neither had the slightest sign of surgical pathology in the abdomen, nor any peritoneal contamination. Third, neither had a so-called sucking wound. These cases were seen within ten days of each other, and have led to some rather definite conclusions concerning this type of injury which, we believe, logically explain the absence of abdominal findings. The theory to be set forth is further supported by a case seen five days after the other two, which presented a left-sided thoraco-abdominal wound involving the stomach, just as the other two, but this patient had, in addition, a sucking wound. Operation in this case revealed no gastric contents in the chest but widespread peritoneal contamination, and would seem to lend further credence to our beliefs.

Very frequently the presence or absence of signs of peritoneal contamination, commonly spoken of collectively as "the acute surgical abdomen," is the deciding factor in time, type or extent of operative treatment and may even be the factor which decides for or against any surgery. The time, as well as the extent, of surgery can be extremely important to the patient's prognosis, as is shown by the first case to be reported, and it is in the hope of clarifying a difficult diagnostic point that these cases are reported.

## CASE REPORTS

**Case 1.**—A white American soldier, age 32, entered a forward echelon hospital at 5:00 P. M., December 5, 1944. He had been wounded in action by an enemy shell fragment at 3:20 P.M. that same day. In other words, he was first seen by one of us 1 hr.



FIG. 2.—Case 1: Foreign body at level of diaphragm, but appears to be above it.



FIG. 1.—Case 1: Showing foreign body (arrow) and widened pericardial shadow.



and 50 min. after he was wounded. Examination revealed the man to be moderately dyspneic, slightly cyanotic, but mentally alert. There was a wound of entrance 8 cm. to the left of the midline in the fourth intercostal space. The wound was 1 cm. in all diameters, and was not sucking. Breath sounds were audible throughout the chest, although decreased over the left base. The pulse was 140, blood pressure 140/110. Heart sounds were very distant and had a slapping character, as if immersed in fluid. The abdomen was entirely negative and bowel sounds were present. Oxygen was started immediately by B. L. B. mask and a small dose of morphine was given.



FIG. 3.—Case 1: Showing foreign body (arrow) and further pericardial widening.

A roentgenogram of the chest (Fig. 1) was taken in the 45-degree sitting posture and revealed a small metallic foreign body just to the left of the midline at the level of the ninth interspace. In addition, the heart shadow was widened and the left costophrenic angle was hazy. The greater curvature of the stomach can be outlined on this film and shows rather well the anatomic position of the stomach, a point to be stressed later. A lateral chest roentgenogram gives the foreign body the appearance of being above the diaphragm but in contact with it (Fig. 2).

After careful consideration, it was decided that this man probably had a ventricular cardiac wound, and, since he was handling it rather well, he should have pericardicentesis and no surgery at this time. Reëxamination of the abdomen at this time was again

completely negative. An attempt at pericardicentesis was made but yielded only 75 cc. of blood. However, the patient's blood pressure came down to 132/90, and the pulse fell to 126. He was then returned to the shock ward, watched closely, and given continuous oxygen.

His condition remained unchanged until 10:30 A.M. the next day, and at that time another roentgenogram (Fig. 3) was taken, and was much the same as the previous one except for further widening of the cardiac shadow. Very shortly after this roentgenogram was taken, the patient suffered an acute circulatory collapse and expired at 11:30 A.M., December 6, 1944, 18 hours after entering the hospital. At no time did this patient have any signs of abdominal involvement.

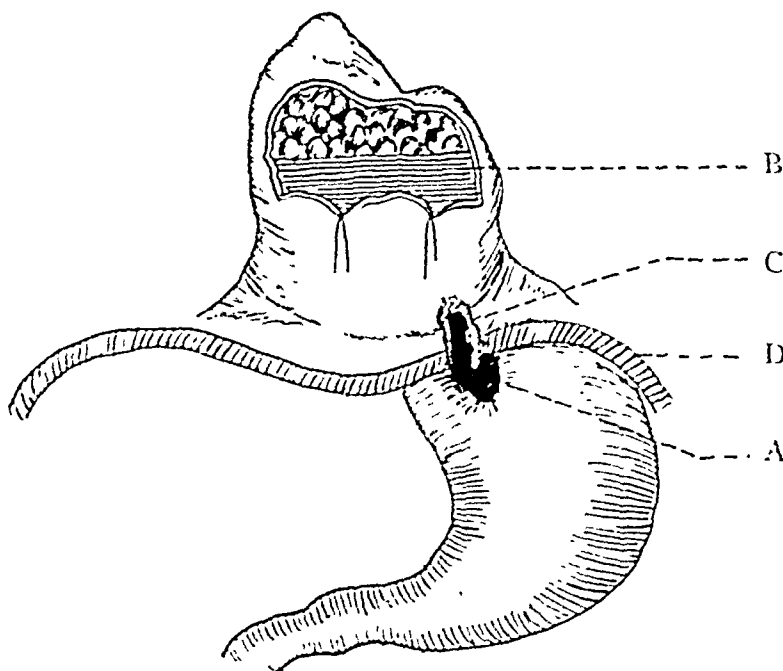


FIG. 4.—Autopsy of Case 1:

- (A) Foreign body in wall of stomach.
- (B) Opened pericardium showing gastric contents and erosion.
- (C) Gastropericardial fistula, traumatic.
- (D) Diaphragm.

Autopsy findings were little short of astonishing. As the pericardium was opened, it was found to be half filled with gastric contents (Fig. 4) and the epicardium and parietal pericardium were reddened and eroded, as if by gastric digestion. At the inferior border of the pericardium was a hole 1.5 cm. in diameter continuous with a hole of similar size in the diaphragm which, in turn, was continuous with a hole in the fundus of the stomach, 3 cm. to the left of the cardia. The foreign body was embedded in the gastric mucosa opposite the hole. The margins of the stomach wound were firmly adherent to the diaphragmatic wound and there was no evidence of even minute contamination of the peritoneal cavity. This man then died of a severe chemical pericarditis and surgery was not undertaken because the abdomen was not thought to be involved, inasmuch as there were no signs of abdominal involvement.

Case 2.—A white American soldier, age 22, entered a forward echelon hospital at 6:00 P.M., December 15, 1944. He had been wounded at 3:25 P.M. the same day, 2 hrs. and 35 min. before being seen by one of us. Examination revealed a wound of entrance,

1.5 cm. in all diameters, at the level of the fourth left interspace in the midaxillary line. The wound was not sucking. Breath sounds were absent and percussion dull to flat over the lower half of the left chest. Blood pressure was 124/80, pulse 104. The abdomen was not tender; bowel sounds were present, and there were no signs of intra-abdominal injury. A roentgenogram, however, revealed a rifle bullet at the level of the second lumbar vertebra and 3 cm. to the left of the midline. It was felt that this patient had a thoraco-abdominal wound, with little or no damage to the abdomen. A seventh-rib thoracotomy was performed, and the left pleural space was found to contain 450 cc. of gastric contents (Fig. 5). The visceral pleura of the lower lobe of the left lung and

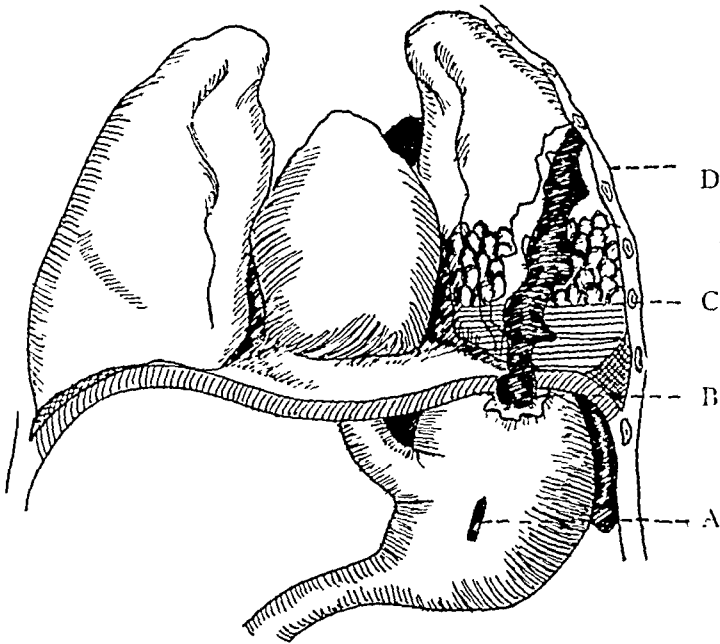


FIG. 5.—Operative findings Case 2:

- (A) Rifle bullet in lumen of stomach.
- (B) Gastropneural fistula, traumatic.
- (C) Gastric contents in pleural space, with erosion.
- (D) Point of entrance, closed.

the left diaphragmatic pleura were reddened and eroded, as if by gastric digestion. There was a 2 cm. perforation of the diaphragm, and as this was enlarged to allow exploration of the upper abdomen, a hole in the fundus of the stomach, 2.5 cm. to the left of the cardia, was found adherent to it. The bullet was in the lumen of the stomach. It was removed and the stomach closed.

There was no sign of peritoneal contamination. The diaphragm was closed and the left pleural space was irrigated with 2,000 cc. of warm, sterile, normal saline, which was aspirated. The lung was reexpanded under visualization by endotracheal positive pressure, and 50,000 units of penicillin solution (10,000 units per cc.) was instilled into the chest. The chest was then closed in layers and a No. 18 F. catheter was placed in the posterior angle of the incision through a stab wound in the latissimus dorsi muscle and attached to a water-seal bottle. The catheter was removed after 48 hours. The patient had an uneventful postoperative convalescence. The lung remained expanded and there were no signs of pleural infection.

The third patient, mentioned previously, had practically the same sort of wound as Case 2, except the wound of entrance was wide open and sucking. This man had widespread contamination of the peritoneal cavity, with no gastric contents in the thorax and, preoperatively, he had a clinically "acute surgical abdomen."

**DISCUSSION.**—It is immediately obvious that when this particular type of wound is present, the absence of abdominal findings is not rare.

It is an anatomic fact that the fundus of the stomach, from the cardia to that point at which the descending portion of the greater curvature begins, is practically in physical contact with the diaphragm. A sagittal section of the body through the middle of the left clavicle (Fig. 6) demonstrates this fact very well. This portion of the stomach wall follows closely the contour of the concavity of the diaphragm. When a missile enters the left chest, and, either by virtue of small size or an exceedingly oblique course (high point of entrance), fails to produce an open pneumothorax, so-called sucking wound, the internal dynamics of the chest are virtually unchanged. That is to say, the normal negative intrathoracic pressure is unchanged. This, in a normal human sub-

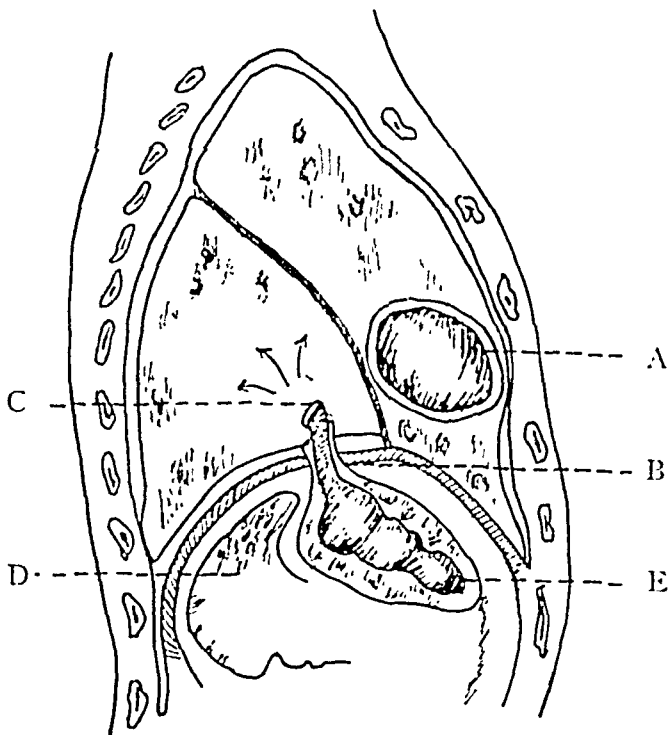


FIG. 6.—Cases 1 and 2: Sagittal section through middle of left clavicle.

- (A) Heart.
- (B) Stomach sucked against diaphragm.
- (C) Gastric contents being evacuated into chest.
- (D) Spleen.
- (E) Stomach, showing close relationship to diaphragm at this point.

ject, in quiet breathing, ranges from minus 6 mm. Hg. in inspiration to minus 2.5 mm. Hg. in expiration. The normal intragastric pressure is plus 6 to plus 10 cm. of water in the upright position, and, even in other positions this pressure rarely, if ever, becomes negative. These are well-established physiologic facts.

If the missile mentioned above penetrates the diaphragm and that portion of the fundus of the stomach in contact with it, and, further, if the missile stops within the stomach, two cavities, one with a negative pressure and one with a positive pressure, are connected instantaneously. We believe that two things take place (Fig. 6). First, the margins of the stomach wound are literally sucked against the margins of the diaphragmatic wound and held there, and, second, the liquid gastric contents are sucked into the chest. The intrathoracic pressure remains negative in all cycles of respiration, so that

the stomach has no opportunity to pull away from the diaphragm. It is this fact, we believe, which accounts for the complete absence of peritoneal soilage and abdominal signs in this type of injury.

The third case lends credence to this explanation in that, in this patient a wide sucking wound was present, destroying the normally negative intra-thoracic pressure, and it was seen that widespread peritoneal contamination resulted. Hence, it follows that when a nonsucking, left-sided thoraco-abdominal wound involving the stomach is present, and the missile remains within the stomach, abdominal signs should not be expected and their absence should not militate against adequate early surgical treatment.

SUMMARY.—Two cases of left-sided, nonsucking, thoraco-abdominal wounds involving the stomach are presented. In both cases gastric contents was present in the chest in sizable quantities. In neither case was there any sign of peritoneal contamination or clinical evidence of abdominal trauma. A physiologic explanation is offered.

#### CONCLUSION

In this particular type of wound no abdominal signs are to be expected and, again, their absence should not deprive the patient of adequate surgery.

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# WOUNDS OF THE URINARY BLADDER

## AN ANALYSIS OF 155 CASES

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IN THE PERIOD January 1, 1944 to May 8, 1945, the surgical teams of an auxiliary surgical group functioning in the Italian, French and German Theaters operated upon 3,154 wounded individuals having abdominal pathology. One hundred fifty-five of these (4.9 per cent) had bladder lesions. There were 19 additional cases with bladder lesions operated upon in the period, November 8, 1942 to December 31, 1943, but these are not included in this report because insufficient data is available on these early cases of the African and Sicilian Campaigns. These 155 cases were operated upon by approximately 30 different teams, the author being the surgeon of one such group.

The diagnosis of bladder lesions is not difficult. The path of the missile, as determined from an alignment of the wounds of entrance and exit, or from the wound of entrance and the location of the foreign body, as determined roentgenographically, will indicate whether the bladder may have been involved. Fracture of the bony pelvis merit investigation, and, in the occasional case, pressure or blast will damage the bladder. In this series of cases the most frequent sites of entry of the missile were through the buttocks (56 times) and anterior abdominal wall (56 times). Other sites of entry were through the thigh, hip, perineum, back and flank. Approximately one-third of the cases had wounds of exit, the missile having left the body. The missile was retained in the other two-thirds. There is nothing characteristic in the abdominal physical findings. Tenderness, rigidity and peristalsis depend to a large measure on the complicating intra-abdominal lesions and the amount of intra-abdominal or retroperitoneal hemorrhage. The presence of an urinary fistula indicates damage to some portion of the genito-urinary tract, as does hematuria. Clear, normal urine does not contraindicate bladder damage. Five of these 155 cases with lesions of the bladder had no blood in the urine. Six cases had an urinary fistula before operation. Filling the bladder with some solution prior to surgery for diagnostic purpose is not recommended. More contaminated material may be forced into the peritoneal cavity, but more important, extravasation of infected fluid may occur retro- and infraperitoneally. Most of these cases have other abdominal lesions and will be subjected to celiotomy anyway, so it is preferable to wait until the abdomen is opened before instilling saline through an urethral catheter. Any intraperitoneal laceration will then be seen directly. In these 155 cases the correct diagnosis was made preoperatively, or at surgery, 149 times. Six cases were overlooked, two of these died the first postoperative day and the bladder wounds were found at autopsy. Three of the six developed urinary fistula (thigh, abdominal wound, and to the rectum) and were later subjected to cystostomy, with satisfactory results. The sixth overlooked case passed a foreign body per urethra, and recovered following the insertion of an indwelling urethral catheter.

In considering mortality in bladder wounds, it is necessary to realize the high incidence of complicating intestinal pathology. One hundred thirty-four of the 155 cases (86 per cent) had bowel lesions, in addition to the bladder damage. In these cases the gastro-intestinal tract injuries merited and received primary consideration. Even in some which did not involve bowel, hemorrhage from the pelvic blood vessels was more serious than the bladder injury, and certainly presented a greater technical problem. All deaths which occurred in cases with bladder damage were complicated by intestinal injury. The mortality rate in cases having bladder lesions depends mainly on how much bowel damage coexists (Tables I and II). There were no deaths in cases with bladder wounds and no coexisting bowel wounds. This seems to indicate that uncomplicated bladder lacerations which are operated upon promptly are not life-threatening. But it is significant that a multiplicity of lesions increases mortality. The mortality rate for 353 cases with only small bowel lesions operated upon by this auxiliary surgical group was 14 per cent. If the bladder was involved along with small bowel (40 cases) the mortality rate was 22 per cent. Similarly, the percentage mortality for 251 cases with only colon lesions was 23 per cent. For colon and bladder lesions coexisting it was 43 per cent.

TABLE I

PERCENTAGE MORTALITY IN WOUNDS OF THE BLADDER WITH AND WITHOUT COMPLICATING BOWEL LESIONS

	Number of Cases	Died	Percentage Mortality
Total cases with bladder lesions.....	155	46	30%
Bladder lesions with complicating bowel lesions.....	134*	46	34%
Bladder lesions without complicating bowel lesions.....	21	0	0%

\* Fifty-five of these 134 involved the rectum.

TABLE II

PERCENTAGE MORTALITY IN WOUNDS OF THE BLADDER WITH COMPLICATING BOWEL LESIONS

Location of Bowel Wound	Number of Cases	Died	Percentage Mortality
Extraperitoneal rectum only.....	6	1	17%
Intraperitoneal rectum only.....	17	3	18%
Small bowel only.....	40	9	22%
Colon only (excludes rectum).....	21	9	43%
Both large and small bowel.....	50	24	48%

The shock-mortality relationship followed the usual pattern. The greater the degree of shock on admission to the hospital, the higher was the mortality rate (mortality rate: 8 per cent no shock, 25 per cent moderate shock and 63 per cent severe shock).

Thirty-five cases were wounded by gunshot, with a mortality of 34 per cent. Seventy-one cases were wounded by shell fragment, with a mortality of 32 per cent. There were three cases of bladder injury classified as due to pressure, with no deaths. In 46 cases the agent causing injury was not recorded.

One hundred thirty-seven of the 155 cases had an intraperitoneal laceration of the bladder. Nine cases had only an extraperitoneal laceration, and none of these died. Nine cases had an extraperitoneal laceration, and one of these

## WOUNDS OF URINARY BLADDER

died. Nine cases had a severe contusion, without a laceration. These last nine all had serious other intra-abdominal lesions, and three of them died.

Surgical procedures carried out for bladder wounds varied very little. One hundred and ten cases had a suprapubic cystostomy, with a repair of the laceration; 13 cases had a suprapubic cystostomy, without repair; six cases had repair, without any other procedure; three cases had an indwelling urethral catheter placed; six cases were overlooked; and seven cases died on the operating table. There is no data available concerning the type of surgery done on ten cases. Repair of the laceration with suprapubic cystostomy is the procedure of choice. The abdomen is opened to explore and repair whatever other intraperitoneal injury is present, and the intraperitoneal bladder is thus easily inspected and repaired at the same time. After closing the peritoneum, the extraperitoneal portion of the bladder can be repaired before doing the suprapubic cystostomy. The space of Retzius is regularly drained. In this

TABLE III

POSTOPERATIVE COMPLICATIONS, 109 CASES WITH BLADDER LESIONS THAT LIVED (17 COMPLICATIONS)

Atelectasis.....	3	Secondary hemorrhage.....	1
Pneumonia.....	1	Pyelitis.....	1
Cardiac failure.....	1	Epididymitis.....	1
Fever, unspecified.....	1	Infected celiotomy wounds (one later eviscerated).....	3
Fecal fistula.....	2	Subphrenic abscess.....	1
Urinary fistula.....	1	Abscess, unspecified.....	1

TABLE IV

ANALYSIS OF DEATHS BY DAY AND CAUSES

Day of Death	Un- known	Misc.*	Shock	Perito- nitis	Chest Compli- cations	Anuria	Embolism	Total
Operation.....	1	4	9	1			1	16
1st postoperative.....			2	1				3
2nd postoperative.....	1		4	3	2	1		11
3rd postoperative.....	1	1		1	1	1		5
4th postoperative.....		1		1	1	2	1	6
5th postoperative.....							1	1
6th-8th postoperative.....	1	1			1		1	4
Total.....	4	7*	15	7	5	4	4	46

\* Miscellaneous deaths: 3 gas gangrene; 2 anesthesia (not definite), 1 heart lesion; 1 retroperitoneal cellulitis

series, sulfonamides were occasionally placed in the abdomen or wound, and in the later cases, penicillin was introduced intra-abdominally. Postoperatively, all patients received sulfonamides orally or intravenously, or penicillin intramuscularly, or both. Three of the nine patients with severe bladder contusions were treated by suprapubic cystostomy (one died), and six received no bladder treatment (two died).

The 109 living cases were followed for from one to 20 days, depending on the tactical situation. Only 25 cases were followed less than five days. There were 17 postoperative complications (Table III), but there was no infection of the paravesicular tissue in any case that lived. There was one retroperitoneal cellulitis in a case that died.



The 46 deaths are analyzed in Table IV. All deaths occurred in cases which had complicating bowel lesions. Early deaths were largely due to shock. Chest complications, urinary suppression and peritonitis were mainly important as immediate causes of death on the 2nd, 3rd and 4th postoperative days. There were three deaths due to gas gangrene of extensive associated wounds.

#### SUMMARY

Data is presented on 155 cases of bladder lesions incurred as war wounds. The physical findings, shock-mortality relationship and wounding agents are presented. The significance of hematuria is discussed, but cases are listed in which bladder lesions occurred without any blood being present in the urine.

The high incidence of complicating intestinal pathology is shown. All deaths occurred in cases which had bowel lesions in addition to the bladder wound. No bladder lesion uncomplicated by a bowel lesion died, indicating that bladder lesions, promptly operated upon are not necessarily life-threatening. It is shown that the mortality rate for small and large bowel lesions is considerably raised by having a complicating bladder injury, indicating the grave significance of a multiplicity of lesions. The treatment of choice has been the establishment of bladder drainage by a suprapubic cystostomy, with repair of the laceration. The space of Retzius was routinely drained, and sulfonamide and/or penicillin were used both locally and systemically. Only one case developed any postoperative paravesicular infection. The complications and immediate cause of death presented are more related to the complicating bowel lesions than to the urinary tract.

# THE SURGICAL TREATMENT OF FUNNEL CHEST\*

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FUNNEL CHEST, which, as the name implies, is a funnel-shaped deformity of the anterior chest wall, has been recognized for many years under many names, such as *pectus excavatum*, *trichterbrust* and *chōnē chondrosternon*, to name a few. Nevertheless, the underlying pathologic condition was not discovered nor a satisfactory operation devised until Brown demonstrated that the deformity was due to a short central tendon of the diaphragm, and described satisfactory surgical treatment. There is an extensive literature on the subject, admirably reviewed by Ochsner and DeBakey, which starts with an article by Bauhinus, in 1594. Since Brown's article appeared Sweet has reported his experience with two cases based on Brown's observations. We are now adding a series of eight cases, the first of which was operated upon two years ago and the most recent one four months ago.

When the deformity is fully developed it is characterized by a deep conical depression of the anterior chest wall the apex of which is at the xiphoid. The sternum shows the greatest displacement. The manubrium is at approximately the normal level but from this point the sternum curves sharply backward until the xiphoid approaches the vertebral bodies. Some cases have been described where the xiphoid was practically in contact with the bodies of the vertebrae, and in our first case the distance separating them was only one centimeter (Fig. 9). The apex of the depression may be in the midline but is often to the right of it, thus, making an asymmetrical funnel. The ribs and costal cartilages attached to the sternum are proportionately involved in the deformity. The ribs tend to flare out laterally and to turn downward and backward at their sternal ends. This is particularly noticeable with the upper ribs and gives a barrel-shape on roentgenologic examination (Fig. 9). The vertebral column is bent forward into an exaggerated dorsal curve (Fig. 8). This, with the chest deformity produces an extreme example of the "round-shouldered, hollow-chested" individual, further heightened by the fact that he is also thin and underdeveloped (Figs. 11 and 12).

The effect of the deformity on the thoracic viscera is that of compression. The lung volume is decreased in proportion to the deformity but seldom to a critical level. The effect on the heart is proportionate to the pressure on it and not necessarily to the degree of deformity. There is frequently a systolic heart murmur, considered to be functional.

Usually, the depression of the sternum pushes the heart into the left hemithorax (Fig. 9) but there may be considerable displacement before the

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\* Read before the New York Surgical Society, December 12, 1945.

pressure affects the heart action. On the other hand, if the heart is prevented from being displaced a moderate depression of the sternum can produce limitation of heart action. The pressure effect is characterized by dyspnea and palpitation on exertion, which may be so great that the patient is practically bedridden. Furthermore, as with other cardiac defects in infancy and childhood, the nutrition is poor and the physical development retarded. In spite of this, the oxygen saturation of the arterial blood appears to be normal. Often there is a psychologic feeling of inferiority—among the boys when they appear unclothed before their fellows, especially when associated with physical

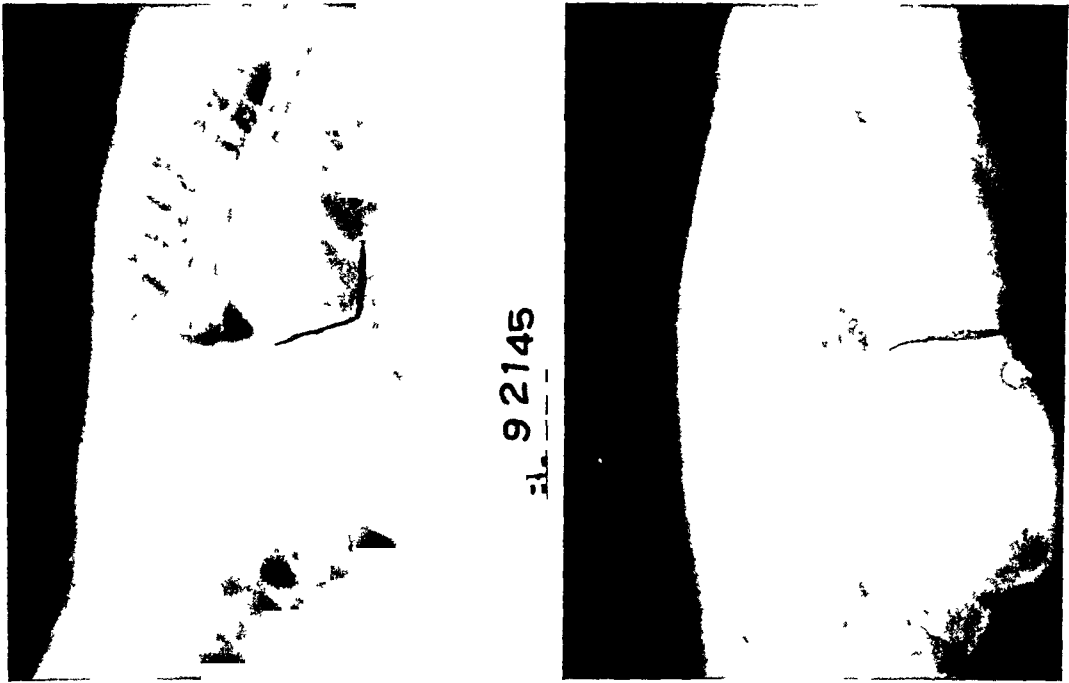


FIG. 1-A

FIG. 1-B

FIG. 1.—Lateral roentgenogram of a case of early funnel chest in an infant. The films were taken for another purpose but illustrate the mechanism of funnel chest.

- (A) During inspiration: The diaphragm is flattened and the xiphoid retracted.
- (B) During expiration: The sternum is in a normal position and the diaphragm somewhat domed.

limitations; and among the girls when they appear in bathing suits or low-necked gowns.

The movement of the thorax during respiration, especially in the vicinity of the deformity, is characteristic of paradoxical respiration. During inspiration the sternum moves backward and the entire funnel deepens, while during expiration the movement is in the opposite direction (Fig. 1). In other words, the movements of the thorax are the reverse of the normal respiratory movements. The explanation of this was discovered by Brown, who noted that the central tendon of the diaphragm was unusually short so that contraction of the muscle exerted a pull on the xiphoid and the costal cartilages of the costal arch drawing them backward (Fig. 1), whereas a normal dia-

phragm by flattening its dome would allow the sternum and ribs to swing out and increase the volume of the chest. This pull on the sternum produces a deformity which is reversible at first, *i.e.*, in early infancy, but when exerted over a long period of time makes the deformity permanent unless corrected.

The permanent deformity is maintained also by the substernal ligament. This is a continuation of the linea alba of the abdomen up along the under surface of the sternum to the suprasternal notch. It is a dense fibrous band closely adherent to the sternum and involved in the attachment of the diaphragm to the xiphoid. In an established case this ligament can maintain the deformity even after the overlying sternum has been resected. Furthermore, it seems to have an abnormal development as a result of the deformity and hence is a structure of great importance in dealing with the correction of the deformity.

The etiology of the deformity is generally considered to be congenital and hereditary. In many cases some other member of the family can be found who has a similar funnel chest and not infrequently several members of the family show the deformity. Other explanations, and there are many of them, have little to recommend their serious consideration with one exception. That is the one which ascribes an obstruction in the respiratory tract as a cause of the deformity.

Dr. L. Emmett Holt, Jr., believes that the shortening of the diaphragm is initiated as a result of forced respiratory efforts to overcome an obstruction somewhere between the carina and the nose or mouth. The negative pressure thus produced causes a depression of the sternum because the cartilaginous portion of the chest is its weakest area. This, in turn, leads to a contracture of the diaphragm which eventually becomes permanent. Certainly respiratory obstruction in an infant, as in the case of pneumonia due to aspiration of amniotic fluid, can produce marked paradoxical respiration with depression of the sternum. Furthermore, four of our cases either had obstruction due to adenoids or gave such a history and one of the infants whose obstruction was unrelieved subsequently developed a depression of his sternum to a certain degree four months after operation. Nevertheless, it is difficult to consider this obstruction as anything other than a contributory cause. Many children have nasal obstruction due to adenoids but few have funnel chest. However, if a child has an obstructive type of breathing the obstruction should be relieved before attempting surgical correction of the funnel chest.

The symptoms and signs just described are not seen in all cases of funnel chest. When they are present operative correction is indicated. Should the patient with obvious funnel chest be without symptoms nothing is to be gained by operation unless the deformity is increasing or the psychologic state suffers as a result of it. Then, even without symptoms, I believe operation is justified. When the deformity is noticed at birth or during infancy there is no indication as to the extent to which it may increase in the future. The condition is reversible at this time and the operation relatively simple. Hence, whether or not symptoms due to funnel chest are manifest every case in an infant which

shows a well-defined tendency to funnel chest should be treated by surgical means, provided any respiratory obstruction has been relieved.

The surgical treatment is of two types: The first, and more simple, is for the early stages of the deformity in infancy and is contrived to release the pull of the diaphragm on the sternum and costal arch. The other is designed to correct a deformity which has been established and must not only release the diaphragmatic pull but must also correct the bony deformity which

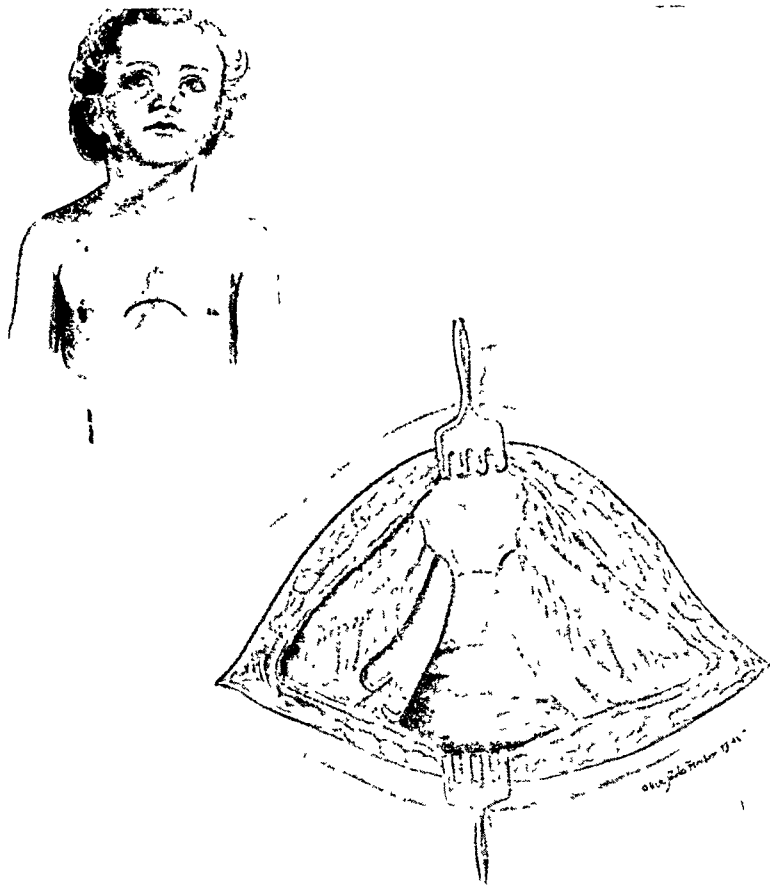


FIG. 2.—The simple operation when the deformity is reversible: The lowest costal cartilage attached to one side of the sternum has been resected showing the depressed xiphoid. Insert shows the incision.

has resulted from this pull. It is obviously a much more extensive procedure. In the main, we have followed the principles and technic described by Brown, but have made some modifications which will be described.

In the first, or reversible group, there are three cases, two infants and the third in a child in her fifth year. In the last case pressure symptoms were beginning to develop and the deformity was established but moderate and we expect that with the pull of the diaphragm released the deformity will disappear as the child grows. In this our expectations are being realized. Two results were entirely satisfactory but one, after several months of satisfactory

## SURGERY OF FUNNEL CHEST

progress, again developed serious respiratory obstruction with a partial return of his deformity.

A curved incision is made about one centimeter above the costal arch with the convexity of the curve cephalad and crossing the midline of the sternum at the highest point of the incision. The skin and subcutaneous

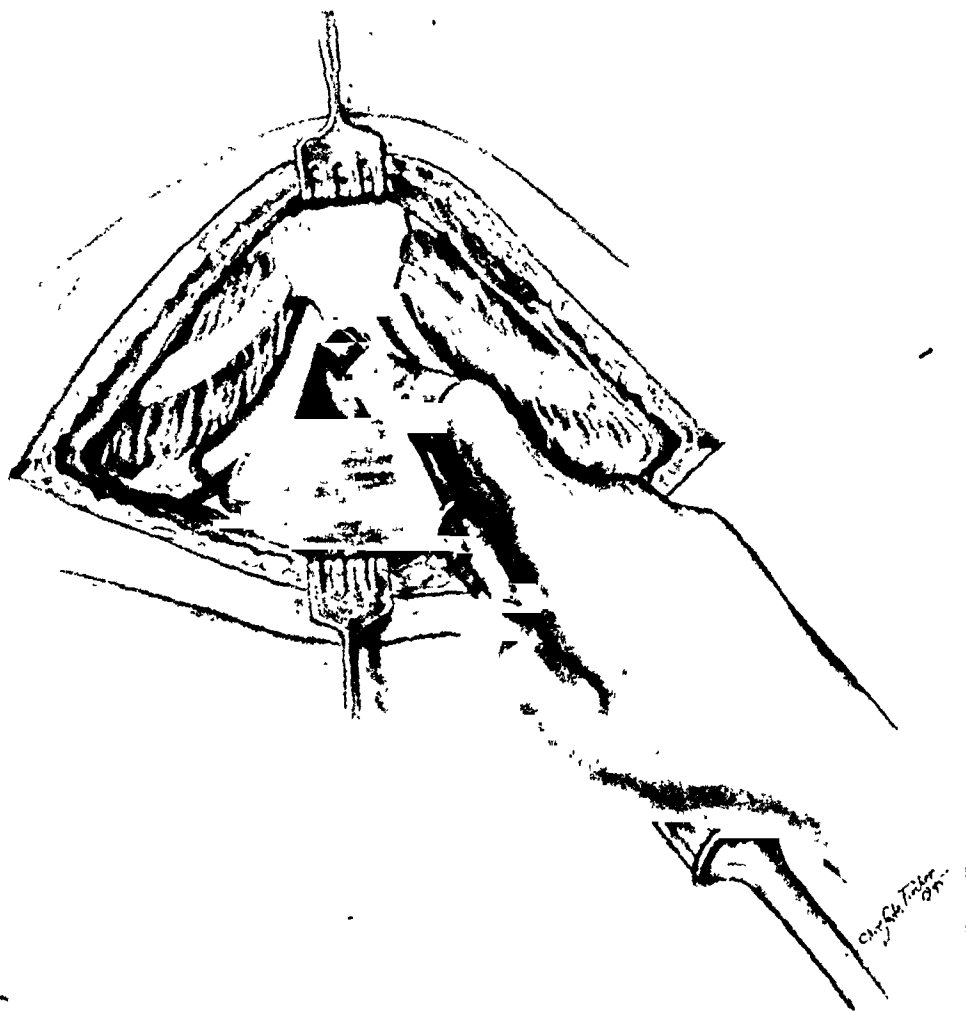


FIG. 3.—The simple operation. The lowest costal cartilage on each side has been resected and the xiphoid separated from the gladiolus, transecting the substernal ligament at the same time. The periosteal elevator is being used to separate the diaphragm from the resected cartilages. Following this the wound will be closed.

tissues of the lower flap are dissected back exposing the two lowest costal cartilages at their sternal ends (Fig. 2). Subperiosteal resection is then performed on the lowest cartilage on each side of the sternum, usually the fused sixth and seventh. Resection is advisable because the opposite cartilages approach each other so closely as a result of the deformity that they cover the xiphoid and make it inaccessible. When they have been resected the lower end of the sternum can be caught with forceps and pulled up, thus exposing the junction of xiphoid and gladiolus. The union is fibrous and is

readily severed with a transverse incision, allowing the diaphragm to pull the xiphoid sharply back. This exposes the substernal ligament, unless, as often happens, the substernal ligament is divided when the xiphoid and gladiolus are separated. Should the ligament remain intact it is severed separately allowing further retraction of the xiphoid and permitting entrance to the ventral mediastinum. A periosteal elevator or similar instrument is next inserted into this space and the diaphragmatic attachments separated from the resected portions of the costal cartilages (Fig. 3). This allows the sternum to spring up to its normal position or at least to approach it. The wound is then closed without drainage.

#### CASE REPORTS

**Case 1.**—M. S., male, six months old, was admitted to the Pediatric Service of Bellevue Hospital, January, 1944, with an acute upper respiratory infection and malnutrition. Aside from frequent colds and coughs he had suffered no illness. At the time of admission he was an anemic undernourished baby. Tonsils were large. There was an acute upper respiratory infection and an associated bronchitis. The increased respiratory effort occasioned by this disease accentuated a funnel deformity of the chest which was not particularly noticeable during quiet breathing. The lower end of the sternum was pulled in sharply during inspiration and relaxed during expiration. When the pulmonary infection had subsided the baby was sent home to await the disappearance of the upper respiratory infection. He was readmitted, in June, 1944, to the Children's Surgical Service for correction of the funnel chest deformity which had become more pronounced during this time. Operation was performed July, 1944. A curved incision was made over the costal arch. The xiphoid was recognized with some difficulty because of the depression and the tendency of the adjacent costal cartilages to meet and obscure it. With great care the xiphoid was severed from the sternum, which allowed the sternum to spring up into a normal position while the xiphoid was drawn backward. A periosteal elevator was then inserted in the opening and the diaphragm pushed off the mesial ends of the costal cartilages. The wound was closed with silk, without drain. Recovery was without incident. The baby has been observed at intervals. Sixteen months after operation the sternum was in a normal position and the respiratory movements were normal. Removal of the tonsils and adenoids has just been done to relieve the frequent upper respiratory infections.

**Case 2.**—G. B., a 16-month-old baby, was admitted to Bellevue Hospital, Pediatric Service, May 15, 1945, with the chief complaint of noisy breathing since birth. His mother cared for him until he was four months old and then boarded him out until he was a year old. During that time his diet was probably deficient as he was weak and underdeveloped when she took him back. The baby has had frequent colds and has had measles and chicken pox.

On examination, the baby appeared undernourished. He breathed with an audible stridor and at times seemed to have a spastic convulsion. Tonsils were small but adenoids large. Heart, lungs and abdomen were normal. The chest showed a typical funnel deformity, the apex being at the xiphoid which was further retracted with each inspiration.

Blood count, blood chemistry and urine were essentially normal; Wassermann, negative. Roentgenograms of chest showed no abnormality of lung fields. Patch test for tuberculosis was negative. Direct laryngoscopy showed a large epiglottis somewhat bent on itself but otherwise was normal.

Adenoidectomy was performed two weeks after admission. Recovery was uneventful. The stridor and retraction of the sternum were not materially affected.

## SURGERY OF FUNNEL CHEST

Two weeks after adenoidectomy operation was performed on the funnel chest. Curved incision was made over the costal arch and the fused sixth and seventh cartilages exposed. The xiphoid could not be identified. Subperiosteal resection was done of the fused cartilages on each side after which the xiphoid could be recognized. It was separated from the sternum by cutting the attachments and at the same time severing the substernal ligament. This allowed the sternum to spring up as the diaphragm pulled the xiphoid back, thus giving access to the uncovered space in the anterior mediastinum. The diaphragm was stripped from its attachment to the resected cartilages in this space and the wound closed without drainage. The child was returned to bed and placed in an oxygen tent. Drop-ether was the anesthetic.

Following operation the immediate condition was good. The first day after operation a serous discharge was noted on the dressing. This persisted for four weeks and eventually ceased when a catgut suture was removed from the wound.

Spastic convulsions and later spasticity of the right side appeared the day after operation and persisted for several days. Convulsions ceased after that but the spasticity disappeared much more slowly and was intermittently present on discharge four weeks after operation.

Follow-up at three months showed the wound well healed. There was no retraction of the sternum on breathing and the funnel deformity had disappeared. Noisy breathing occurred when the child had a cold but not otherwise. There was a partial paralysis of the right side. Two months later stridor was present all the time and with forced inspiration there was some slight retraction of the sternum as a whole and not of the lower end alone as before operation. The child has gained weight and, except for his slight paralysis is much better than before operation.

Case 3.—C. C., a white girl, five years of age, was admitted to the Hospital for Special Surgery, March 20, 1944, with the complaint of poor posture, funnel chest and underdevelopment. There are no other funnel chest deformities in the family although all have a poor posture and another child has a pigeon breast deformity.

The birth history was not unusual. The mother noticed a funnel chest deformity when the baby was born and this has gradually increased and with it an exaggerated dorsal curve of the spine has developed. The child has not developed properly, gains weight slowly and becomes dyspneic on exertion. She is a mouth breather and has frequent colds.

Physical examination shows a poorly developed girl of five years. Tonsils and adenoids are enlarged. There is a funnel-shaped deformity of the anterior chest wall involving the sternum and adjacent costal cartilages which deepens during inspiration. The apex of the funnel corresponds to the xiphoid, which on roentgenologic examination is three centimeters from the vertebral column (Fig. 8). The heart is displaced somewhat to the left but is otherwise not abnormal. The remainder of the physical examination is essentially normal except for the presence of an acute upper respiratory infection on admission. This necessitated deferring the operation for a week.

Operation was performed, April 1, 1944, under drop-ether anesthesia. A curved incision was made over the costal arch and the sixth and seventh costal cartilages on each side exposed and a subperiosteal resection performed on them. The attachment of the xiphoid to the gladiolus was severed exposing the substernal ligament which was then divided. The diaphragmatic attachments to the resected cartilages were then freed with a periosteal elevator and the gladiolus allowed to spring up. It did not attain a normal position but did come up enough to relieve any pressure on the heart. The wound was closed without drainage.

Convalescence was uncomplicated. The wound healed by primary union, and the child was ready for discharge on the twelfth postoperative day. Postoperative roentgenograms showed little change in the distance between vertebrae and sternum but the dorsal curve had straightened into normal position (Fig. 8).

Eight months after operation the child was readmitted for removal of tonsils and



adenoids, which was accomplished without incident. Eighteen months after operation she was in excellent general condition, there was no dyspnea on exertion and she was gaining weight in a satisfactory manner. The funnel depression, although still present, was less marked and seemed to be correcting itself. There was no pull on it during inspiration.

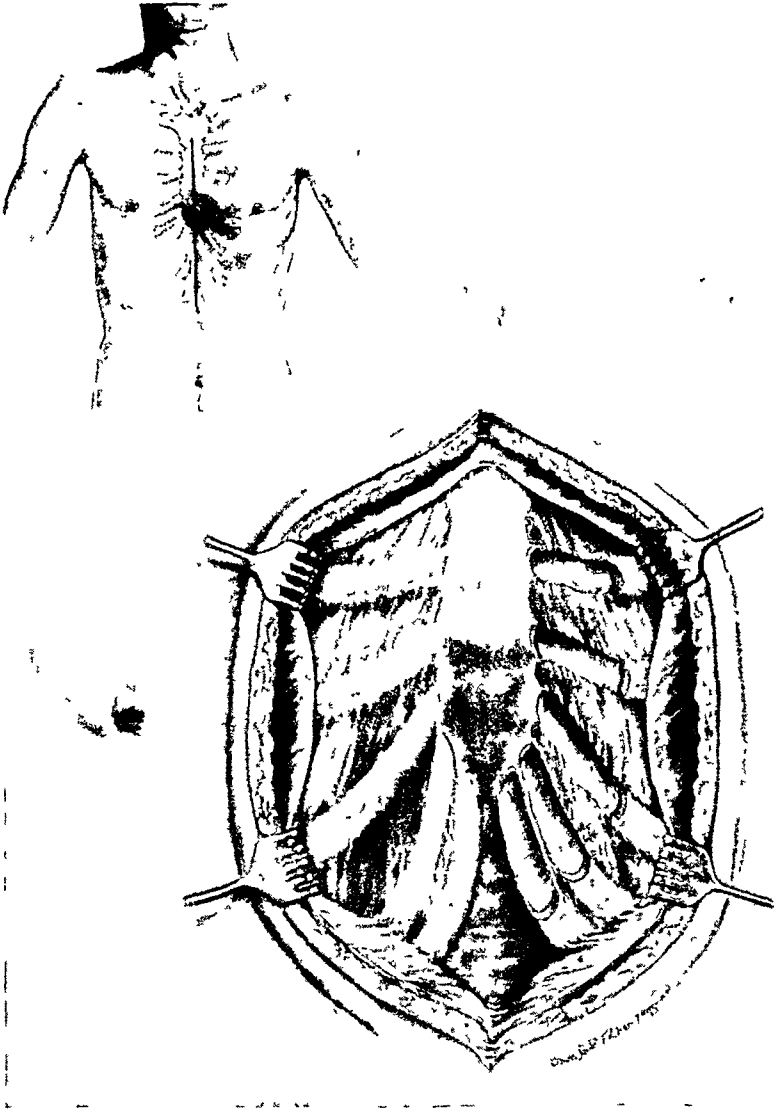


FIG. 4.—The radical operation for established deformity: The cartilages attaching to one side of the sternum, up to the second, have been resected back to the bony ribs and the xiphoid exposed. Insert shows the incision.

COMMENT.—These are cases representing the relief of the deformity by a simple type of operation. The appearance of the depression in the second case may be ascribed to the recurrence of the respiratory obstruction and it is not a recurrence of the funnel chest, but we have classed it as not entirely satisfactory. An established deformity cannot be corrected by this type of operation but if it is minimal it may be expected to improve with the growth of the child if the diaphragmatic pull is relieved.

The fully developed deformity requires a much more extensive procedure for its correction. Release of the diaphragm must be accomplished by separating the xiphoid from the gladiolus, severing the substernal ligament and freeing the anterior midline attachments to the diaphragm from the costal arch as in the simple operation just described. This, however, does not allow the sternum to assume a normal position. For this to be accomplished it is necessary to resect the costal cartilages and transect the gladiolus just below

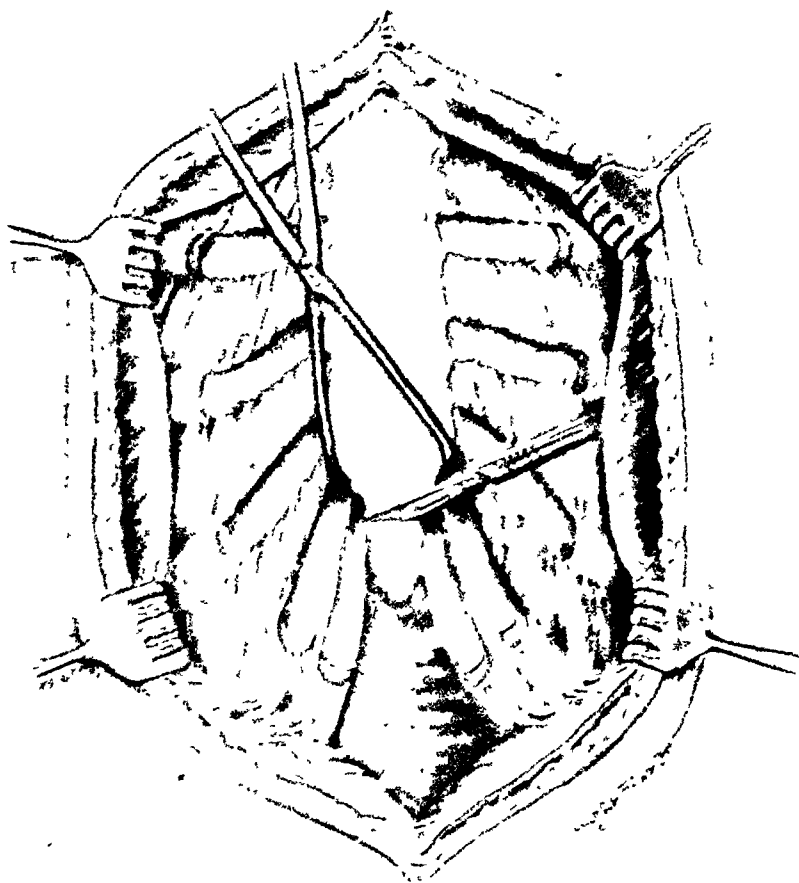


FIG. 5.—The radical operation: The costal cartilages on both sides have been resected and the xiphoid is about to be severed after elevation of the sternum with forceps demonstrates the junction of xiphoid and gladiolus. The substernal ligament will be severed at the same time.

the manubrium, raise the sternum and then maintain it in its new position, until it has become stabilized, by means of an external appliance which Brown calls a Jacob's ladder.

Our first two cases were treated according to the technic described by Brown, with resection of about two centimeters of the costal cartilages and stabilization of the sternum by wiring it to the resected ends of one of the lower cartilages, the wire then being taken out through the skin and fastened into the Jacob's ladder. Dramatic relief was afforded in one case with partial

correction of the deformity. In the other case symptoms were relieved but the deformity recurred, although to a lesser extent than originally. The third case was operated upon with Sweet's modification, which sutures the sternum to the resected cartilages on both sides. Somewhat better correction of the

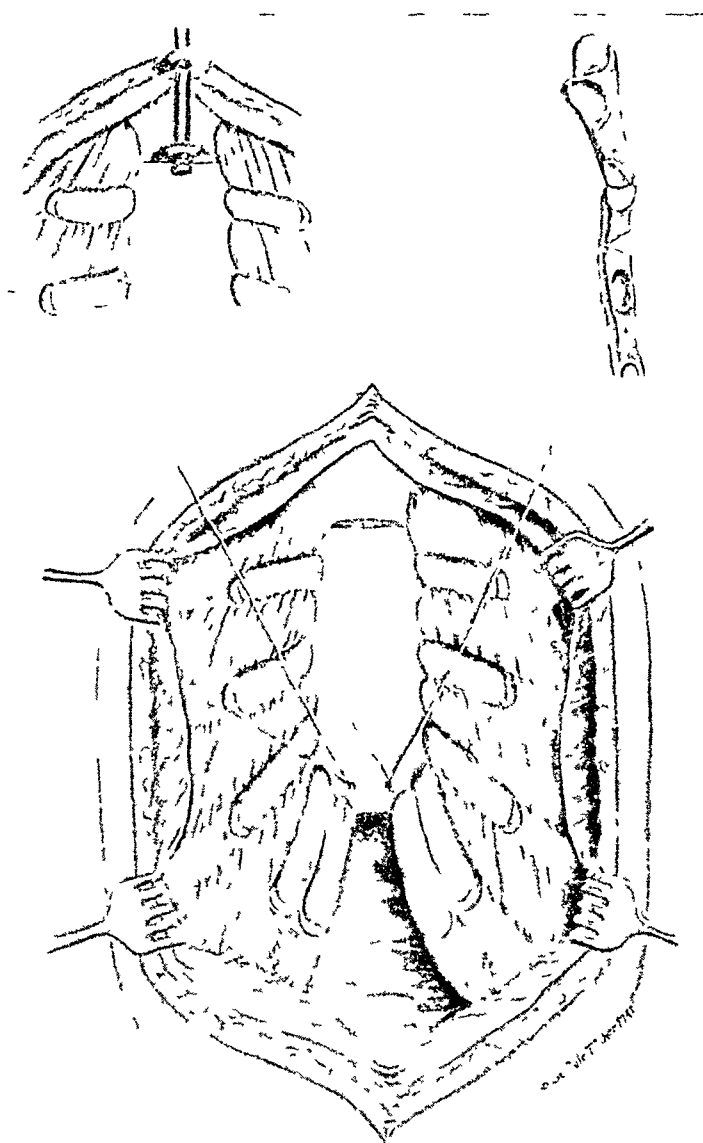


FIG. 6—The radical operation: The outer table of the sternum has been cut transversely just below the second rib (wedge osteotomy indicated in inserts) and silver wire threaded through drill holes in the lower end of the sternum.

deformity was obtained and the pressure symptoms relieved although the heart murmur persisted.

It is to be noted that in none of these cases was the deformity completely corrected, actually not more than 75 per cent in the best. To achieve complete correction it is necessary to perform a subperichondrial resection of the costal

## SURGERY OF FUNNEL CHEST

cartilages back to the point where the rib begins to deviate from its normal course and to similarly resect a portion of the rib also if that be required. Regeneration of the costal cartilage and rib will then take place with the rib in a more or less normal position. This, of course, precludes the possibility of stabilizing the sternum by any suture to the rib ends. However, stability can be obtained first, by transecting only the outer table of the sternum below the manubrium and, leaving the inner table intact, bending the sternum up

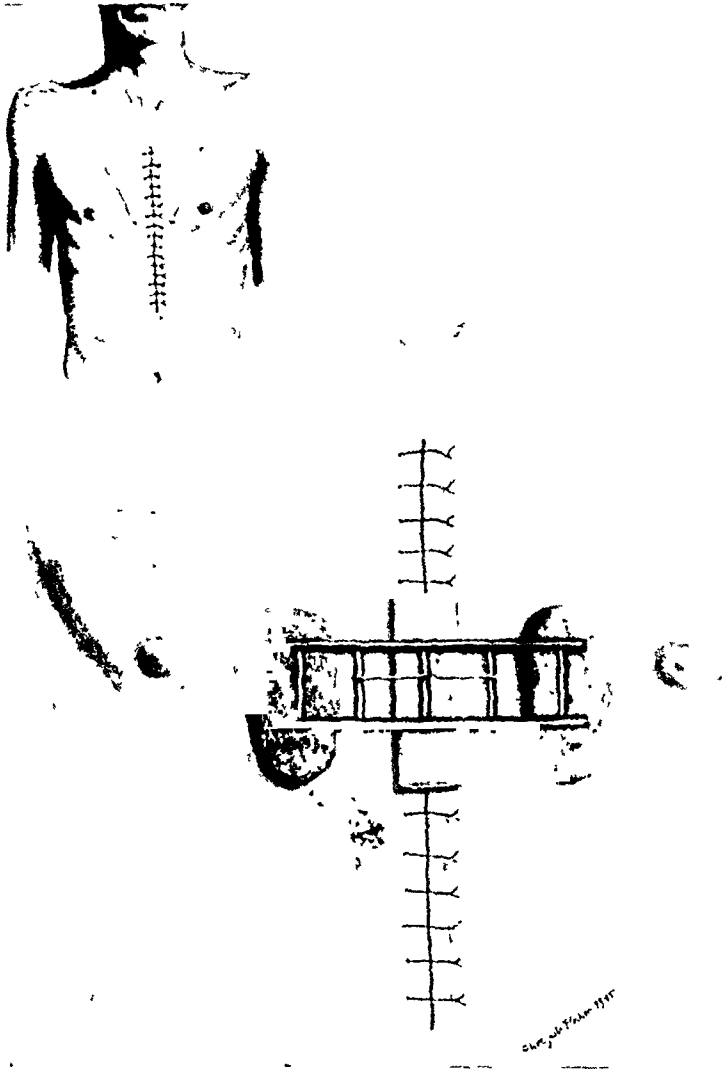


FIG. 7.—The radical operation: The wound is closed and the wires carried out through the skin on each side of the incision (insert) and fastened into the ladder.

into place, making a sort of greenstick fracture. The wire sutures employed by Brown and Sweet have not seemed necessary to us and we have never used them. The second factor in maintaining the stability is the use of a Jacob's ladder. This will hold the sternum in its new position and prevent paradoxical respiration. The ladder must be left on until a certain amount of stability in the chest wall has taken place. Judging by the length of time required to obtain stiffening after thoracoplasty we have left the ladder in place ten days. Three weeks should be ample, and probably unnecessarily long.

In one of our cases the wire broke on the sixth day thus disposing of the ladder in less than a week and nothing untoward developed.

A longitudinal incision is made over the midline of the sternum starting at the level of the second rib and extending down onto the abdomen a third or half the distance between xiphoid and umbilicus. The skin flaps are mobilized to give adequate exposure and the pectoralis major and rectus abdominis muscles separated and retracted from sternum and costal cartilages

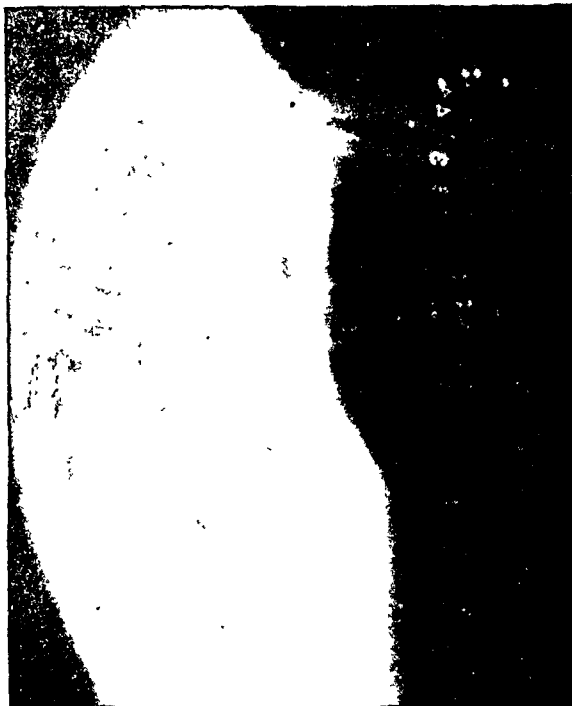


FIG. 8-A

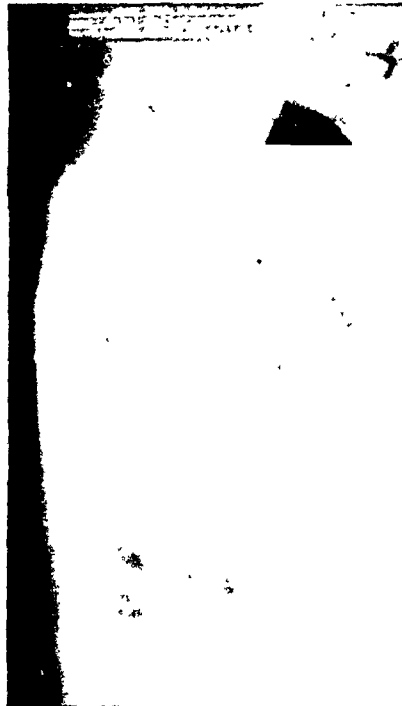


FIG. 8-B

FIG. 8.—The effect of the simple operation on the exaggerated dorsal curve of the vertebral column.

(A) Before operation.

(B) After operation.

(Fig. 4). Even with this exposure it is very difficult to identify the xiphoid because the deformity buries it under the cartilages of the costal arch. Sub-perichondrial resection is then performed on the cartilages from the sternum laterally to the start of the deformity but not taking more than the third. The lower end of the sternum is next grasped in forceps and drawn forward to demonstrate the xiphoid-gladiolus attachment which is cut (Fig. 5). The substernal ligament is severed at the same time. The pull of the diaphragm immediately widens the separation giving access to the ventral mediastinum. Occasionally, in a young individual, the sternum may be elevated into its normal position by fracturing it along the cartilaginous line between the second and third segments. If this proves impossible a transverse wedge of bone is removed from the outer table of the upper part of the third segment,

care being taken not to cut the inner table, and the sternum elevated into its proper position by making a subperiosteal fracture of the bone at this site.

Brown advocates leaving the substernal ligament intact and separating the sternum from it without entering the mediastinum. The substernal ligament is divided later. With our first patients we followed this plan but in one case the substernal ligament was so densely adherent to the periosteum of the under surface of the sternum that heavy, sharp periosteal elevators had to be used in the relatively inaccessible area under the sternum and the pleura was torn. Since then we have divided the substernal ligament with the xiphoid and had no hesitancy in entering the mediastinum. If the substernal ligament is found intact after the sternum has been elevated it must be completely divided. If this is not done the deformity is only partly corrected and is sure to recur.

After the sternum is elevated two drill holes are placed in its lower portion just above the free end and a silver wire threaded through them with the free ends brought out of the wound (Fig. 6). The pectoral and rectus muscles are sutured to each other across the midline of the sternum and the skin wound closed without drainage. Before closing the skin the ends of the silver wire are brought out onto the chest wall through punctures in the skin flaps. The Jacob's ladder is padded and laid across the chest wall where the wire emerges and the wire drawn up and twisted into the ladder (Fig. 7). This elevates the sternum into its proper position and holds it there, thus preventing paradoxical respiration as well. The ladder must be secured firmly with an adhesive dressing. It is removed ten days to three weeks later depending on the stability of the chest wall.

All the wounds healed by primary union but three of them subsequently opened at their lower ends and discharged serous fluid from the dead space left by the elevation of the sternum. The sinuses thus formed were rather slow to heal but pus never developed and there were no bad effects from it. This would seem to indicate that fear of mediastinitis is exaggerated.

Five cases have been treated by surgical operation. All have received relief from their pressure symptoms. With regard to the deformity the result was excellent in one case, satisfactory in three and unsatisfactory in one. There were no deaths.

#### CASE REPORTS

**Case 4.**—R. H., a six-year-old girl, was admitted to the Pediatric Service of Bellevue Hospital, December 3, 1943, complaining of fever, cough, running ear and dyspnea on exertion. She had had measles and frequent colds, coughs and running ears. A year ago she had been a patient at Bellevue Hospital, with running ears and upper respiratory infection.

Ever since birth the child had had a funnel chest deformity. In spite of this her infancy had no serious disturbances but during the past few years she has suffered increasingly from dyspnea on exertion and the funnel chest deformity has been deepening. She has been a patient in the cardiac clinic for systolic and diastolic murmurs and cardiac incompetence. This was thought to be due to the funnel chest and on her previous hospital stay operation was advised for this deformity. It was not done because of parental

objections. The cardiac condition is now so bad that she is unable to play with other children or even to run 50 feet. As a result she has become a social problem and is irritable, morose and unresponsive. Her appetite is poor and her development, both physical and mental, is retarded.

Physical examination shows a sullen, resistant child, poorly nourished and sitting in bed in a stoop-shouldered posture. External strabismus of the right eye is present. Both ears have perforated drums with purulent discharge. Moderate enlargement of cervical lymph nodes is noted. Heart displaced to left with apex in midaxillary line. Rate rapid and regular; loud systolic and diastolic murmurs. Lungs not remarkable. Abdomen and extremities not remarkable. Chest is the site of a marked funnel deformity with the xiphoid so deeply depressed that it cannot be felt (Figs. 9 and 11). Laboratory data: R. B. C., 5,070,000; Hb., 15 Gm.; W. B. C., 18,000, 70 per cent polys. Urine: Normal.



FIG. 9-A

FIG. 9-B

FIG. 9.—The irreversible deformity: Postero-anterior and lateral roentgenograms before operation. The apex of the heart is at the axillary chest wall and the xiphoid is only 1 cm. in front of the vertebral column.

With sulfadiazine and general hygienic treatment the ears ceased to discharge and the cough disappeared. Her temperature which was 101° F. on admission dropped to normal on the third hospital day, and her general condition improved steadily. Operation for repair of funnel chest deformity was undertaken three weeks after admission.

A curved incision was made starting over the left second costal cartilage swinging to midline and then back along the left seventh costal cartilage. The sternum was exposed by dissecting back the pectoral and rectus abdominis muscles. The fourth, fifth and fused sixth and seventh costal cartilages were then stripped of their perichondrium for a short distance and about 1.5 cm. of each resected. Access was thus gained to the under surface of the sternum which was separated from the substernal ligament by blunt and sharp dissection. This exposed the junction of xiphoid and gladiolus which was severed. The substernal ligament was then identified and severed, allowing the sternum to come up and the xiphoid to be pulled sharply backward. The sternum was then elevated into place by fracturing it along the junction of its third and fourth segments which had not yet ossified. The resected ends of the fifth left costal cartilage were

## SURGERY OF FUNNEL CHEST

approximated by a stainless steel wire which was carried out through the skin and fastened to a Jacob's ladder on the chest wall. The wound was closed without drainage.

Postoperative course was uneventful. The child was placed in an oxygen tent for three days. On the sixth day the wire broke and the ladder was removed. The wound was well healed on the seventh day and the sutures removed (Fig. 10), but the child was kept in bed for three weeks to avoid the dangers inherent in a ward full of children. The general response to the operation was dramatic. The child was no longer sullen and unresponsive. She took an active interest in her surroundings and when allowed out of bed was so active that she had to be restrained. Never having been able to run

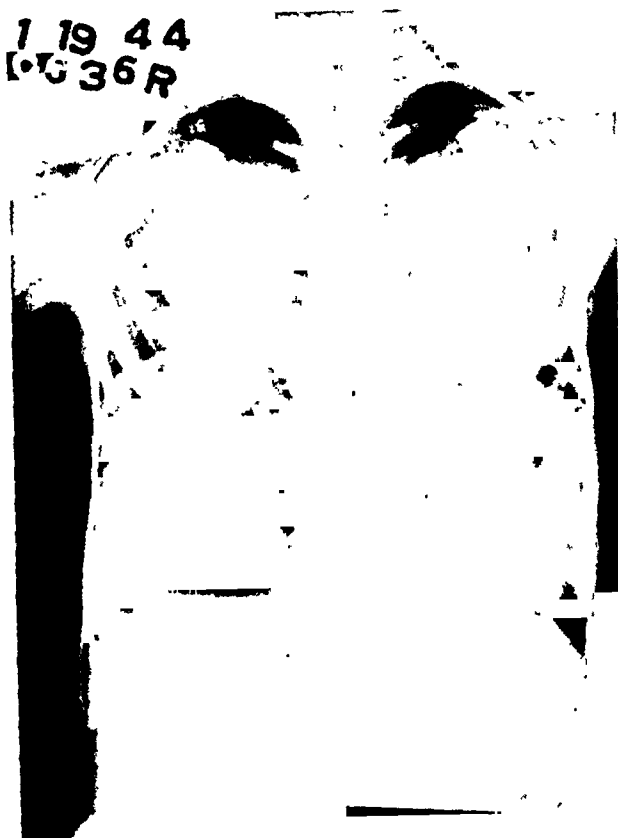


FIG. 10-A



FIG. 10-B

FIG. 10.—The irreversible deformity: Postero-anterior and lateral roentgenograms after operation. The sternum has been elevated and the heart has moved away from the axillary chest wall.

before, the novelty of it so appealed to her that she ran all over the place. She was discharged five weeks after operation. Eighteen months after operation she was well, active and leading the normal life of a child of her age. The funnel depression was about 75 per cent corrected, but she was entirely relieved of her symptoms.

Case 5.—G. C., a 13-year-old boy, was admitted to the Hospital for Special Surgery, August 10, 1944, complaining of depressed sternum. His past and family histories had no bearing on the present condition. The deformity of his sternum was noticed at birth and it was becoming deeper. He had had the usual childhood diseases. The deformity limited his action somewhat and he found that he could not keep up with the other boys with whom he played, although when at rest there was no evidence of dyspnea. He is a shy, diffident boy who offers no objections to instructions but consistently fails to carry them out unless he wants to. This is felt to be the result of his deformity. During the preceding six months the distance between xiphoid and vertebral column has decreased by one centimeter.



Operation was performed August 11, 1944. A longitudinal incision was made over the midline of the sternum and flared-out along the costal arch in the shape of an inverted Y. The sternum and costal cartilages were exposed and the lower three costal cartilages on each side were resected. The sternum was divided just above the xiphoid and the substernal ligament separated from the sternum with great difficulty. While using a periosteal elevator beneath the third segment the right pleura was damaged and a pneumothorax established as a result. The sternum was fractured along the junction of the third and fourth segments and the sternum elevated into its normal place. The substernal ligament was then divided and a transverse section one centimeter wide was removed. Attempt was then made to close the tear in the pleura, but without success, so a flap of muscle was raised from the pectoralis major on the right and sutured into the tear. With this in place it was not necessary to fix the sternum because the interposed muscle prevented it from dropping into its original position. The wound was closed without drainage, and all the air possible was aspirated from the right pleural space. The boy was returned to bed and placed in an oxygen tent. Fluid and air were aspirated from the right pleural space on two occasions allowing the lung to reexpand in five days when the oxygen tent was discontinued. Recovery was uneventful thereafter except that the boy was entirely unresponsive to all suggestions regarding posture and exercise to prevent recurrence of the funnel chest. Nevertheless, roentgenograms three weeks after operation showed the sternum in a normal position. Serous drainage developed in the lower end of the wound and persisted for six weeks but eventually ceased and the wound healed. One year after operation he was able to play tennis without undue fatigue or dyspnea but his funnel chest had recurred and the tip of the sternum was only one centimeter farther from the vertebral column than before operation. Functionally the result was satisfactory but physically the deformity was but little improved.

**Case 6.**—V. M., a 17-year-old white male, was admitted to Bellevue Hospital July 24, 1944. His chief complaint was funnel chest deformity since early infancy and a cough of two weeks duration. There were no other funnel chest deformities in the family. He had pneumonia at the age of two and appendicectomy at the age of 14. Past history was otherwise irrelevant.

He had noticed the deformity in his chest as long as he can remember. He develops some dyspnea on exertion and for that reason he has been unable to do all in the way of physical exercise that his companions do. He thinks this exertional dyspnea has been increasing. He has had a cough for two weeks.

Physical examination shows the patient to be round-shouldered and underweight but otherwise normal in appearance. The chest is the site of a funnel deformity with the xiphoid forming the apex of the depression and lying but three centimeters from the vertebral column (roentgenographic measurements). The sternum and costal cartilages enter into the funnel deformity; the lower ribs flare out and the upper ribs produce a barrel chest laterally (Fig. 12). The manubrium sterni is in its normal position but the sternum curves backward from this point to the xiphoid.

The heart is markedly displaced to the left and shows tachycardia, precordial heave and coarse systolic murmurs in aortic and mitral areas. Lungs show a mild acute respiratory infection at both bases. Fluoroscope shows the diaphragm to move little, if any, during inspiration. Electrocardiogram showed right axis deviation. Lung volumes were 60 per cent of normal and ventilation 70 per cent.

Operation was postponed until August 7th to allow the respiratory infection to subside. Under endotracheal cyclopropane anesthesia, a longitudinal incision was made over the midline of the sternum from manubrium to xiphoid and extended along the costal arch from this point to make an inverted Y. The skin, subcutaneous tissue, pectoral muscles and rectus abdominis muscles were reflected laterally exposing the sternum. Beginning at the fused sixth and seventh the cartilages on both sides were resected sub-perichondrially for about two centimeters each up to and including the third. The sternum

## SURGERY OF FUNNEL CHEST

was drawn up by forceps and the xiphoid severed from the gladiolus. This had little effect on the deformity until the substernal ligament was likewise severed and the diaphragmatic attachments pushed off from the resected costal cartilages for 2 cms. on each side of the xiphoid. The sternum could then be elevated but would not stay in place until a wedge osteotomy was performed across the second sternal segment taking the outer table but leaving the inner intact. A silver wire was then threaded through two drill holes in the lower end of the sternum and the free ends brought out onto the chest wall on either side of the incision. The muscles, subcutaneous tissues, and skin were then closed over the sternum and the ends of the wire twisted into a Jacob's ladder placed across the chest in such a manner as to fix the sternum in its normal position.



FIG. 11-A



FIG. 11-B

FIG. 11.—Photographs of patient R. H., whose roentgenograms are shown in Figure 10 A and B, before and after operation, respectively.

The postoperative course was complicated by the drainage of serous fluid from the lower end of the wound but this ceased after two weeks and the wound healed. The ladder was removed at the end of the third week and the sternum remained elevated in its normal position although there was still a slight depression of the sternum. One year after operation (Fig. 12) the boy is able to play football without distress and has gained weight and strength. He still continues to have his heart murmur. His lung volume has increased to 75 per cent of normal and his maximum breathing capacity in a like proportion. The depression is still present to a slight degree but seems to be lessening.

Case 7.—I. S., a four-year-old boy, of Puerto Rican parents, was admitted to Bellevue Hospital, December 29, 1944, referred by Dr. E. Guilfoil. The chief complaint was increasing funnel chest deformity. His birth history was not unusual. He had pneumonia 18 months ago and bronchitis two weeks ago. His tonsils were enlarged and he had suffered from frequent sore throats. There are two siblings neither of whom has a funnel chest.

At birth the mother noticed no abnormality of the chest but when the child was about a year old a depression appeared over the end of the sternum which has become increasingly deeper. There were no symptoms of cardiac embarrassment.

Physical examination showed a fairly well-nourished Puerto Rican boy of four. Tonsils were enormous and almost met in the midline of the pharynx. His voice was affected by the tonsils but not his breathing. Lungs normal; heart displaced to the left with normal rate and roughened first sound at the apex. EKG was normal. Abdomen showed no abnormalities. The chest presented a marked depression of the lower end of the sternum with flaring of the lower costal cartilages and a well-established funnel chest. The xiphoid was further retracted on inspiration.



FIG. 12-A

FIG. 12-B

FIG. 12.—Patient V. M. Irreversible deformity before and after operation.

Operation was performed January 8, 1945. Under ether anesthesia administered through an intratracheal tube, a longitudinal incision was made from manubrium to xiphoid where it was extended to form an inverted Y along the costal arch. The pectoral and rectus abdominis muscles were separated from their sternal attachments and retracted laterally. The seventh, sixth, fifth and fourth costal cartilages were resected on each side and the sternoxiphoid articulation developed. This was transected through into the uncovered space severing the substernal ligament at the same time. Thus released, the xiphoid was retracted back and the sternum was easily elevated into its normal position without the necessity of performing an osteotomy of the sternum. The resected ends of the fifth cartilages were sutured by a single black silk suture on each side and the lower end of the sternum held up by a silver wire looped under the lower end of the sternum and carried out onto the chest wall where the ends were fastened into a Jacob's ladder. The wound was closed without drainage.

The postoperative course was uneventful except for some slight infection around the wire holes. Sutures were removed on the seventh day and the ladder and wire on the ninth. The patient was discharged February 8, 1945, with wound healed.

## SURGERY OF FUNNEL CHEST

Five weeks later he was readmitted, with the history of a draining sinus at the lower end of the wound of 19 days duration. A silk suture was removed from the sinus, whereupon it healed promptly. Seven months after operation his tonsils and adenoids were removed. Eleven months after operation the sternum is in a nearly normal position but there is still a slight depression and a slight flare to the lower costal cartilages. The deformity seems to be decreasing as the child grows. His general condition is excellent in all respects.

Case 8.—C. D., a nine-year-old white girl, was admitted to the hospital, July 25, 1945, with the chief complaint of funnel chest deformity. The mother states that the deformity has been present since birth but that it has not increased materially lately. She becomes short of breath on exertion and tires easily. A systolic heart murmur was noted by Dr. Clarence E. de la Chapelle who considered it due to the pressure on the heart by the sternum and referred her for operation.

She is an only child and there is no history of other funnel chest deformities in the family. Her past history is noncontributory.

Examination shows a thin but otherwise healthy child of nine. The sternum shows a marked depression deepest at the xiphoid which is displaced to the right, thus giving an asymmetry to the deformity. The manubrium is in a normal position but from this point the sternum curves backward and to the right carrying with it the costal cartilages which enter into the formation of the funnel as far lateral on each side as the bony ribs. The funnel deepens on inspiration. The heart is displaced into the left chest and has a systolic murmur. The remainder of the physical examination is essentially normal.

Operation was undertaken July 26, 1945. Under intratracheal ether anesthesia, a longitudinal incision was made from manubrium to halfway between umbilicus and xiphoid. The skin, subcutaneous tissues and pectoral and rectus abdominis muscles were reflected laterally. Subperichondrial resection was then done of the fused sixth and seventh, fifth, fourth and third costal cartilages on each side back to the bony rib. The xiphoid was detached from the manubrium and the substernal ligament divided at the same time. The diaphragmatic attachment to the fused sixth and seventh costal cartilages was freed. Even with this amount of liberation it was not possible to elevate the sternum until a transverse wedge osteotomy was performed removing the outer table of the sternum a little above the third rib. The sternum could then be raised into a normal position. Two drill holes were made in the lower end of the sternum and a silver wire threaded through them with the loose ends carried out through the skin on each side of the incision. Nothing else was done to stabilize the sternum. The muscles, subcutaneous tissues and skin were then sutured together and the ends of the silver wire were twisted into a Jacob's ladder placed across the chest. The child was returned to bed and put in an oxygen tent.

The postoperative course was uncomplicated. The oxygen tent was discontinued the second day after operation. The skin sutures were removed on the seventh day and the ladder on the tenth. The patient left the hospital two weeks after operation.

Six weeks after operation the chest wall was solid and the deformity corrected except for a slight flattening of the anterior chest wall. Four months after operation the same good result continues. The murmur is still present but to a much less degree.

COMMENT.—These cases represent the deformity after it has become established. In all cases the substernal ligament and the costal cartilages had to be resected to allow the sternum to come up to a normal position and in all but one it was necessary to fracture the sternum either through the cartilaginous union of the segments or by means of a wedge osteotomy of the sternum in its second segment. Relief of cardiac pressure can be obtained without complete correction of the deformity. To obtain maximum correction of the deformity subperichondrial resection of the cartilages must be performed

back to the bony rib and it may even be necessary to resect part of the bony rib. Stability of the sternum can be obtained by the use of a Jacob's ladder which must be left on until sufficient regeneration of cartilage or bone has occurred to fix it in the normal position. With one exception the late results have been satisfactory.

#### SUMMARY

Funnel chest is a deformity of the sternum characterized by a funnel-shaped depression of the sternum with the apex at the xiphoid. It is caused by a short central tendon of the diaphragm which pulls the xiphoid backwards during inspiration. It may produce pressure on the heart causing palpitation, dyspnea on exertion (sometimes extreme) and chronic malnutrition and underdevelopment. In infancy, when the deformity is in a reversible stage a simple operation suffices to correct it. Later, when the deformity has become fixed, a much more extensive operation is necessary. Operation results in a high percentage of satisfactory results.

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# THE USE OF TESTOSTERONE PROPIONATE IN THE TREATMENT OF ADVANCED CARCINOMA OF THE BREAST

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NUMEROUS INVESTIGATORS, stimulated by the researches of Lacassagne and of Loeb, have demonstrated that the administration of the estrogenic hormones produces mammary carcinoma in mice. An attempt to counteract this carcinogenic effect of estrogens by means of androgens was a logical consequence. That this result could be achieved in animals was early established by several investigators (Raynaud, Lacassagne, Murlin, and his collaborators).

This principle of inhibiting the activity of the gonadal hormones of one sex by the administration of the gonadal hormones of the opposite sex has been employed in recent years in the treatment of human cancer. Encouraging results have been obtained in the treatment of prostatic cancer by the estrogens.

There are, however, surprisingly few reports of the use of androgens in the treatment of human carcinoma. In 1939, publications by Ulrich, and by Loeser, described favorable changes in patients with advanced carcinoma of the breast coincident with the administration of testosterone propionate. The latter author, in 1941, reported additional cases which appeared to be favorably influenced by this therapy. In a recent publication, Fels obtained gratifying results in one of three patients treated with testosterone propionate.

Farrow and Woodard (1942), on the other hand, using small doses of testosterone propionate concluded that in certain instances osseous metastases from breast carcinoma were stimulated by this agent.

We have investigated the effects of large doses of testosterone propionate on advanced carcinoma of the female breast. Eleven patients received this treatment, four of whom have to date exhibited a favorable response. The abstracts of these four case histories follow:

## CASE REPORTS

**Case 1.**—S. K., a 63-year-old married white woman, 13 years postmenopause, was admitted to the Clinic on January 30, 1945. She had noticed a mass in the right breast near the nipple in August, 1939. She was a Christian Scientist and, therefore, paid no attention to the mass until about four years later, at which time it had become very large. This, however, gave her no great concern but a mass in the right side of her neck, which had been increasing in size for four months, alarmed her. She feared it might strangle her, and for that reason she sought medical attention.

The physical findings on February 1, 1945, were as follows (Fig. 1). The right breast was elevated, nipple retracted and stuck flush with the areola margin. The breast was completely replaced by a hard, nodular mass but was still somewhat movable on the chest wall. The skin overlying the mass was pinkish in color and there was pigskin appearance most marked on the medial and lower aspects of the breast extend-

ing over to the sternum. There was an area of redness and impending ulceration just medial to the areola border and there was a similar area on the inferior aspect of the breast. The left breast was negative. There were numerous skin nodules, some 0.5 cm. in diameter, extending on to the abdominal wall. There were several similar nodules

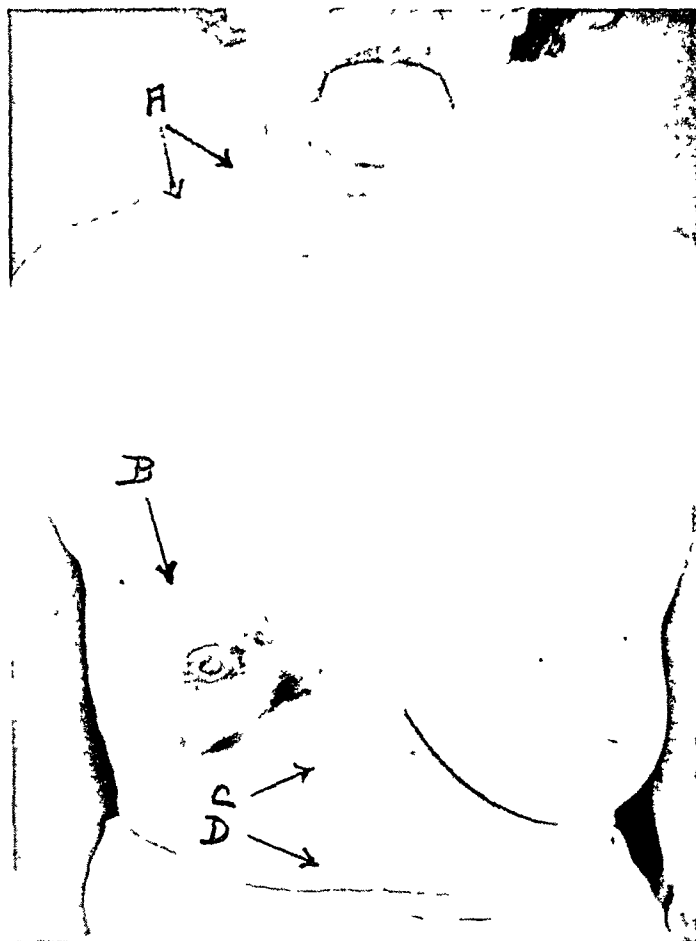


FIG. 1.—Case 1: Photograph shows the lesions before instituting testosterone propionate therapy. A group of enlarged nodes may be seen in the right supraclavicular area (A). The right breast is completely filled with a large mass whose nodules are discernible; one large protruding mass is seen just above the areola (B). Below the areola there is an extensive area with pigskin appearance and dimpling. Medial to the areola is an area of impending ulceration. Below this is a similar larger area in which ulceration is imminent. Medial to these areas and extending almost to the opposite breast is another area of *peau d'orange* appearance. Two nodules, one higher than the other, may be seen in the skin of the right upper abdomen near the midline (C and D).

in the skin overlying the right scapula. The right supraclavicular space was filled with a hard, fixed, nodular mass with several hard nodules in the right postcervical chain extending to the level of the mastoid process. There were numerous nodules in the skin of the right neck. There were several hard, shotty nodules in the left supraclavicular space. Numerous large hard nodes were palpable in the right axilla.

Biopsy of the breast was reported as infiltrating duct carcinoma and an excised

## TESTOSTERONE PROPIONATE IN CANCER

skin nodule revealed mammary carcinoma involving the lymphatics. Roentgenograms of the chest, lumbar spine and pelvis were *negative for metastases*.

*Therapy.*—On March 2, 1945, 300 milligrams of testosterone propionate in pellets were implanted subcutaneously. From March 5 to March 24, 1945, 2,600 milligrams of testosterone propionate were administered intramuscularly in 200 milligram doses.



FIG. 2.—Case 1: This photograph was taken about 3.5 months after the preceding one. Within this period the patient had received 3,975 milligrams of testosterone propionate. The right supraclavicular nodes are no longer present. No nodules can be seen in the breast. The protuberant mass above the areola is no longer present. Likewise, the areas of impending ulceration and of pigskin appearance have entirely disappeared leaving the skin of the breast smooth. The upper skin nodule in the abdominal wall was removed for examination. The scar of the excision may be seen. The lower nodule has completely disappeared.

Over an interval extending from March 24 to June 6, 1945, 25 milligrams of testosterone propionate were injected intramuscularly three times a week. The total dose administered up to June 6, 1945 was 3,975 milligrams.

*Progress.*—Examination on April 17, 1945, about one month after instituting the therapy, revealed the right supraclavicular mass to be very much smaller. Nodes were no longer palpable in the right postcervical chain. The skin nodules in the neck and



in the scapula region were no longer present. Only one minute, soft node was palpable in the right axilla.

Examination on April 14, 1945, revealed the right breast to be soft and freely movable on the chest wall. The areas of redness on the medial and inferior aspects of the breast were markedly diminished in extent and the masses underlying these areas were much smaller and softer. No supraclavicular or axillary nodes were palpable.

On May 12, 1945, some increase in facial hair was noted and, on May 19, 1945, two skin nodules which had persisted in the right upper anterior abdominal wall were no longer discernible.

The physical findings on May 26, 1945, were as follows: There was a slight pink coloration of the medial aspect of the right breast with slight induration underlying it. No masses were palpable in the breasts. The areas of impending ulceration in the right breast were no longer present. No lymph nodes were palpable in the cervical, supraclavicular or axillary regions. No skin nodules were present (Fig. 2).

Roentgenograms of the chest, lumbar spine and pelvis made at this time were negative for evidence of metastatic disease.

	LABORATORY DATA						
	2/1/45	2/13/45	2/15/45	3/9/45	3/31/45	4/21/45	6/2/45
Blood:							
Hb . . . . .	84		70		79	82	78
R. B. C. . . . .	4	3.5	3.5		3.9	3.9	3.8
W. B. C. . . . .	6.5				6.7	5	8
Polys . . . . .	77				84	77	88
Lymphs . . . . .	22				15	23	
Monos . . . . .	1				1		12
Hematocrit . . . . .		34%	32%			32%	
Alkaline phosphatase . . . . .	1.6			2.1			2.4
Serum phosphorus . . . . .	3.5			2.7			3.78
Serum calcium . . . . .	11.1			10			10.6
Urine:							
Sp. gr. . . . .		1.005					1.010
Albumin . . . . .		0					0
Sugar . . . . .		0					0
Micro. . . . .		0					0
Body weight (lbs) . . . . .	126			130		135.5	131.5

The gain in weight of 9.5 lbs. in 11 weeks coincided with the disappearance of the lesions. The subsequent weight loss was due to a throat infection which interfered with swallowing.

**Case 2.**—A S, a married white woman, age 47, underwent a radical mastectomy for a Grade 3 infiltrating duct carcinoma of the left breast in 1935. The lymph nodes were not involved. In 1937, she underwent roentgen castration as a prophylactic measure. The patient was asymptomatic, and apparently free of disease until January, 1945. At that time she complained of pain in the lower back radiating down both thighs to the legs. Roentgenologic studies of the lumbar spine and pelvis failed to reveal metastases. The pain continued to increase. Roentgenograms taken 2.5 months later (April 9, 1945) revealed extensive metastases to the lumbar spine and pelvis. The chest was negative for metastases. Physical examination revealed no other evidence of disease.

**Therapy.**—From April 14, to June 28, 1945, she received a weekly intramuscular injection of 200 milligrams of testosterone propionate, for a total dose of 2,400 milligrams.

**Progress.**—When she began treatment she was unable to walk without aid and could not sleep because of pain in the lumbar spine and hips. Some relief was obtained from large doses of codeine. The pain gradually subsided and, on May 19, 1945, she was asymptomatic.

On June 1, 1945, roentgenograms were again taken of the lumbar spine and pelvis. Compared with those taken in April, 1945, a slight increase in density in the areas of metastases was noted.

Roentgenologic studies made on June 21, 1945, revealed a further increase in the density in the bones involved by the metastases, indicating still further osteoblastic change since the earlier films were made. These changes may be seen by a comparison of Figures 3 and 4. The patient has remained asymptomatic to date. Aside from the regressing process in the lumbar spine and pelvis there is no evidence of disease.

LABORATORY DATA				
	4/9/45	4/28/45	5/10/45	6/7/45
Blood:				
Hb.....		56		60
R. B. C.....		2.7		2.9
W. B. C.....		9.3		5
Polys.....		58		60
Monos.....		5		
Lymphs.....		37		40
Serum calcium.....	11		10	10
Alkaline phosphatase.....	5.5		21.5	25.2
Serum phosphorus.....	4.07		2.52	2.86
Body weight (lbs.) .....	122.5		131.5	137

The gain in weight of almost 15 lbs., and the great increase in the serum alkaline phosphatase are noteworthy.

Case 3.—S. K., a 42-year-old single white woman, menstruating regularly, consulted the Clinic December 6, 1944. She became aware of a painless mass in the left breast one year previously but failed to seek medical advice. About two months prior to admission the breast began to pain, and she noticed that the skin over it was dimpled, the nipple retracted and that it was now smaller than the opposite breast. One month later she began to experience pain in the left lumbar region which extended to the buttock and radiated down the posterior aspect of the left thigh. Because of this pain it was difficult for her to walk or change position when sitting or lying, and for this reason she came to the Clinic.

Examination revealed an elevation and deformity of the left breast with retraction of the nipple and areola. There was pronounced dimpling involving most of the breast integument. In the subareola region, extending outward on the 5 o'clock radius was a poorly-outlined mass measuring 2 x 3 cm. There were several small firm nodes palpable in the left axilla. There was no supraclavicular adenopathy.

Aspiration biopsy of the breast mass was reported as carcinoma. Roentgenograms of the lungs were negative but those of the lumbar spine and pelvis revealed numerous areas of bone destruction which were interpreted as carcinoma metastases. The patient failed to return to the Clinic after this preliminary investigation, and it was subsequently learned that she suffered a psychic disturbance which necessitated her being hospitalized.

Three months later, March 1945, she returned. During her stay in the mental institution she received 1,300 r to the left breast. There was no other therapy to the primary site and none to the metastatic lesions. Physical findings were essentially the same as at the previous examination. However, in addition to the pain in the lumbar region which made walking difficult, she now complained of pain in the cervical spine and in the left shoulder.

Roentgenograms, made March 20, 1945, revealed metastases to the bodies of the cervical vertebrae, to the outer third of the left clavicle, to the neck and glenoid of the left scapula and to the head of the left humerus. There were widespread metastases to the lumbar spine and pelvis (Figs. 5 and 6).

*Therapy.*—On March 10, 1945, 300 milligrams of testosterone propionate in pellets were implanted subcutaneously. From March 12 to March 31, 1945, she received 2,400 milligrams of testosterone propionate intramuscularly in doses of 200 milligrams. From March 31 to June 21, 1945, she received 1,400 milligrams of testosterone propionate intramuscularly in 25 milligram doses. The total dose administered was 4,100 milligrams.

*Course.*—On April 7, 1945, the pain in the right hip was diminished. Examination of the left breast on April 28, revealed it to be less deformed and the mass smaller and softer. On May 19, 1945, she complained of pain in the upper right ribs in the axillary region, and roentgenologic studies disclosed evidence of extensive metastases to the right ribs. On May 26, 1945, she reported amenorrhea for the preceding two

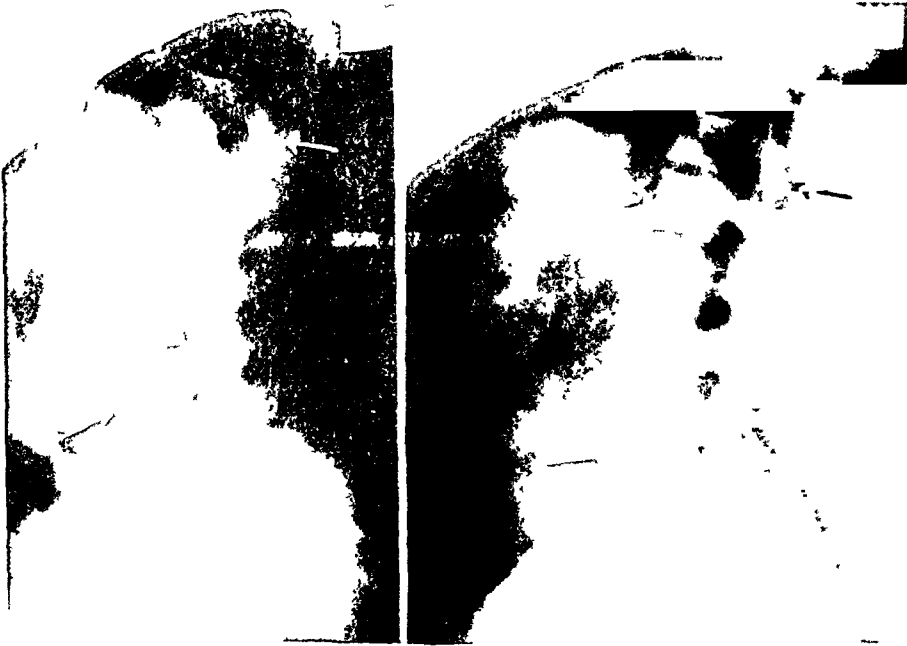


FIG. 3

FIG. 4

FIG. 3.—Case 2: All of the lumbar vertebrae are involved by metastases. Note the lack of density in the bodies and transverse processes.

FIG. 4.—Case 2: The increased density of the bodies and transverse processes of the vertebrae due to a deposition of calcium is readily appreciated by comparison with the preceding figure. There was an interval of three months between this and the preceding roentgenogram during which time the patient received 2,400 milligrams of testosterone propionate.

months. There was marked facial hirsutism. June 9, 1945, she stated that she had had no pain in the cervical spine for the past month. Pain in lumbar spine and hips was less. Roentgenologic studies were reported as follows: "A comparison of the films of the cervical spine made June 5, 1945, with those made on March 20, 1945, shows a marked change in the appearance of the metastases. There is now a diffuse increase in density in the bodies of the lower cervical vertebrae and in some areas of the remaining vertebrae. This change is also present in the laminae and transverse processes as well as in the upper ribs visualized" (Fig. 7).

"A comparison of films of the lumbar spine, pelvis and left shoulder girdle made June 12, 1945, with those made March 20, 1945, reveals a striking change in the appearance of the metastases in all areas. There is the same diffuse increase in density as was noted in the cervical spine" (Fig. 8).

June 21, 1945: The patient feels well and has no pain. The mass in the left breast and the left axillary nodes are still palpable.

RESPIRONATE IN CANCER									
LABORATORY DATA									
	12/6/44	3/8/45	3/23/45	3/31/45	4/20/45	5/29/45	6/5/45		
Blood:									
Hb.....	87	62		65				73	
R. B. C.....	4.6	3		3.2				3.4	
W. B. C.....	12.2			8.4				9.2	
Polys.....	58			46				42	
Monos.....	3			2				4	
Lymphs.....	38	21%		49				48	
Hematocrit.....									
Serum calcium.....	11.7		12.5		18%				
Alkaline phosphatase.....	3.9		4.9		11.4	10.7			
Serum phosphorus.....	3.10		3.79		9.3	9.4			
Urine:					2.92	3.02			
Sp. gr.....	0	1.013						1.008	
Albumin.....	0	0						0	
Sugar.....	0	0						0	
Micro.....	0	0						0	
Body weight (lbs.).....	120		124		126.5	128		130	

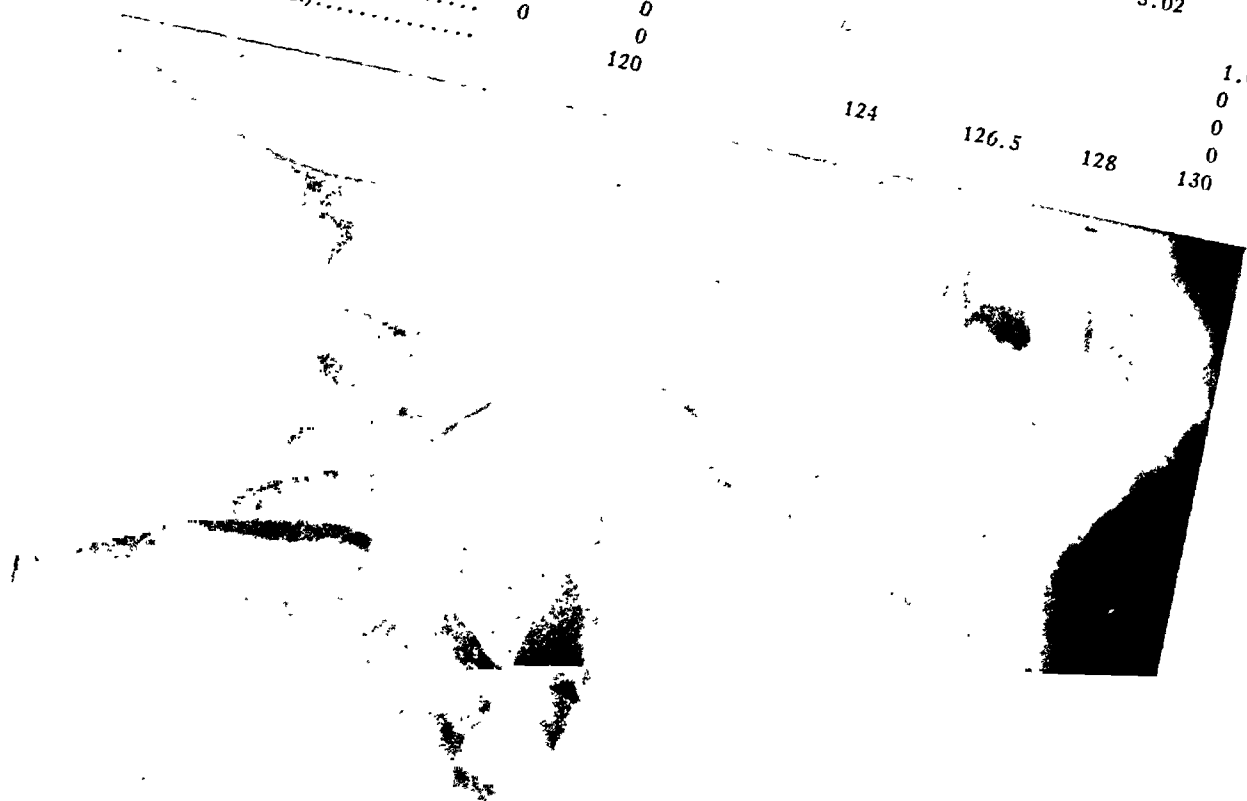


FIG. 5.—Case 3: Shows metastatic disease involving all of the cervical vertebrae with collapse of the 6th.

The gain in weight (10 lbs.) and the increase in serum alkaline phosphatase were the significant changes.

Case 4.—D. F., a 44-year-old white woman, menstruating regularly, consulted the Clinic in October, 1944, because of a mass in the right breast of one year's duration. A diagnosis of carcinoma was made and a radical mastectomy performed. Pathologic examination revealed an infiltrating duct carcinoma Grade 3; axillary lymph nodes clear. She received a cycle of postoperative roentgenotherapy to the right axilla through three ports. She was asymptomatic and apparently free of disease until March, 1945. At this time, she complained of pain in the lower part of her back radiating down the left thigh posteriorly. The pain was so severe that she could not sleep. Large doses

1029



FIG 6—Case 3: There is extensive metastatic involvement of the lumbar spine, pelvis and femora.



FIG 7.—Case 3. This is a roentgenogram taken about 3.5 months later. The increased density of the vertebral bodies due to the deposition of calcium is striking. During the interval between the first and second roentgenograms the patient received 4,100 milligrams of testosterone propionate.

of codeine did not control it. Roentgenograms revealed evidence of a large area of destruction in the left ala of the sacrum (Fig. 9). She was given testosterone propionate, 200 milligrams daily, for one week, and 25 milligrams three times a week for ten weeks. The total dose administered was 2,150 milligrams.

*Course.*—At the end of the first week of treatment the pain was less and she was able to sleep, something she had been unable to do for three weeks preceding the treatment. The pain gradually subsided until at the end of the eighth week she was entirely free of pain. Roentgenologic studies during this period disclosed a progressive regenera-

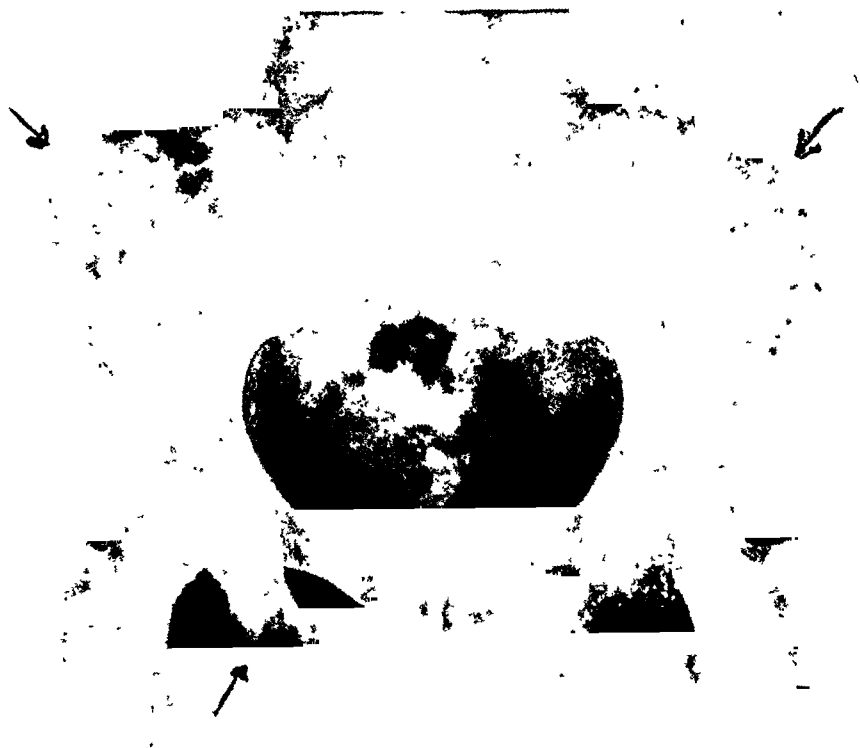


FIG. 8—Case 3: An increase in calcification after testosterone similar to that revealed in the cervical spine is seen by comparing this roentgenogram with the preceding one. Arrows call attention to a few of the more prominent metastatic areas which have decreased in size or disappeared altogether. There is pronounced calcification of the lumbar vertebrae and alae of the sacrum.

tion of bone in the area of destruction in the left ala of the sacrum (Fig. 10). At the end of June, three months after the initiation of testosterone therapy the patient resumed her work as a comptometer operator. She was asymptomatic at this time and, aside from the calcifying lesion in the ala of the sacrum, there was no evidence of disease. The therapy produced an amenorrhea and some facial hirsutism.

There was some gain in weight but no significant change in serum alkaline phosphatase.

*COMMENT.*—In a number of the patients under investigation the expected masculinizing effects of testosterone; namely, hirsutism and deepening of the voice, were encountered. Amenorrhea was produced in those women in whom menstruation had been present before instituting the therapy. An increase in libido, as noted by Shorr and coworkers and Abel, was found in some instances.

Large doses of testosterone produced no discernible effect on the blood picture or renal function as judged by routine examination of the urine. All of the patients who improved under testosterone therapy exhibited an increase

in weight. This may have resulted from the nitrogen retention which is produced by the testosterone. On the other hand, the relief from pain and the consequent ability to sleep may have been contributory factors in the weight gain.

Changes in the serum content of alkaline phosphatase were manifest in two of the three patients described above with bone metastases (Cases 2 and 3). Alkaline phosphatase is produced by bones which are attempting to repair damage from metastases or other causes, and its serum level may, therefore, be used as an index of bone regeneration. It is not clear why the third case, despite marked osteoblastic changes, failed to reveal the expected serum phos-

LABORATORY DATA				
	10/11/44	3/22/45	4/19/45	5/29/45
Blood:				
Hb.....	82		80	71
R. B. C.....	3.9		4	4
W. B. C.....	7.2		9.2	10.6
Polys.....	58		71	80
Monos.....	1		2	
Lymphs.....	41		27	20
Serum calcium.....		11.7	11.4	12
Serum phosphorus.....		3.6	3.78	3.64
Alkaline phosphatase.....		2.5	2.9	3.1
Urine:				
Sp. gr.....	1.018			1.020
Albumin.....	0			0
Sugar.....	0			0
Micro.....	0			0
Body weight (lbs.).....	159	163	161.5	163 1/8

phatase increase. The serum calcium and phosphorus remained within normal limits in all cases. A rise might have indicated an increase in the osteolytic process.

Of the seven patients who failed to show improvement with testosterone therapy two are dead. One had pulmonary and the other liver metastases. Another, who was in a very advanced stage when testosterone therapy was instituted has been unable to continue because she lives in a distant city. A fourth patient had generalized osseous metastases and a serum calcium of 15.5 milligrams per cent when first seen. She received 1,000 milligrams of testosterone propionate within a period of five days. This produced a further increase in the serum calcium associated with nausea, vomiting and depression. The clinical picture was similar to that described by Farrow and Woodard in patients with osseous metastases who had received small amounts of testosterone propionate. Cessation of testosterone therapy produced a drop in the serum calcium and a disappearance of the toxic manifestations. After a lapse of time, during which the serum calcium remained stabilized at about 14 milligrams per cent, testosterone propionate was again cautiously administered. The calcium level once more began to rise and the patient again became nauseated, therefore, this therapy was discontinued. Roentgenologic studies revealed progressive changes in the bone lesions. It would appear that testosterone is contraindicated in patients with hypercalcemia associated with osseous

# TESTOSTERONE PROPIONATE IN CANCER



FIG. 9.—Case 4: A large area of metastatic disease involving the left ala of the sacrum is seen.

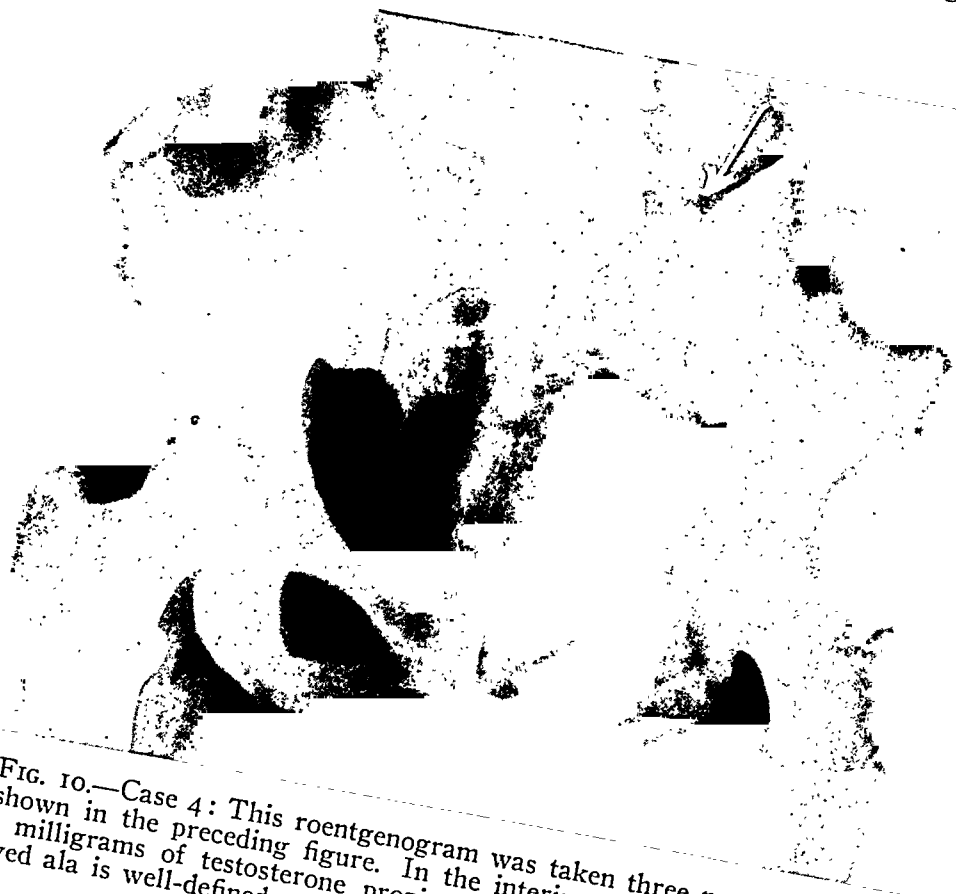


FIG. 10.—Case 4: This roentgenogram was taken three months after the one shown in the preceding figure. In the interim the patient had received 2,150 milligrams of testosterone propionate. The increased density in the involved ala is well-defined.



metastases. The importance of routine blood chemical studies in patients receiving testosterone therapy is obvious.

The three remaining patients are still under treatment. All have widespread soft-part metastases but no osseous involvement. Although these patients have not as yet exhibited clinical regression it is too soon to predict the ultimate outcome. It is of interest that biopsies of skin nodules in two of these cases have shown cellular changes. These cellular alterations are described by Dr. Fred Stewart as follows: Of the nodule in one case he says: "Mammary carcinoma. Rather marked focal hydropic degeneration. Mitoses still present." His description of the nodule from the other case is: "Mammary carcinoma. Cells definitely hydropic and nuclei pyknotic. Rare mitoses still seen. The tumor does show distinct differences from the expected."

It is of interest that similar hydropic changes in the cells of prostatic carcinoma have been observed after the administration of estrogens (Shenken, Burns and Kahle).

#### SUMMARY AND CONCLUSIONS

1. Eleven cases of advanced breast cancer, treated with large amounts of testosterone propionate, are reported.
2. No toxic effects were noted in individuals with normal serum calcium levels, each of whom received several thousand milligrams of testosterone propionate over a period of three months.
3. Four patients, one with soft-part and three with osseous metastases manifested remarkable improvement.
4. The evidence of improvement was the regression of the primary lesion and soft part metastases in one case and an increase in calcification in areas of osseous metastasis in three cases.
5. Disappearance of pain coincided with the osteoblastic changes.
6. In two of the cases that exhibited deposition of calcium in the bone metastases there was a coincident elevation of the serum alkaline phosphatase.
7. Four patients did not respond to the therapy and three others are still under treatment, without clinical evidence of improvement. Metastatic nodules from two of the latter group, on microscopic study, revealed hydropic changes.
8. One patient with an initial hypercalcemia associated with osseous metastases manifested a further rise in serum calcium associated with toxic manifestations in consequence of testosterone therapy. This emphasizes the importance of blood chemical studies in patients receiving this treatment.
9. We believe that testosterone propionate in large doses may, in certain instances, exert a favorable influence on advanced carcinoma of the female breast.
10. The number of cases studied is too small to gauge the frequency of this favorable reaction. From our limited experience the beneficial effects are unpredictable and uncertain. Likewise, the duration of the favorable response and the amount of testosterone propionate necessary to maintain this improved status is as yet unknown.

The authors wish to thank Dr. Helen Q. Woodard of the Department of Chemistry, Memorial Hospital, for making the blood chemical studies embodied in this report. We also are indebted to the Schering Corporation of Bloomfield, N. J., for furnishing us with the testosterone propionate (Oreton) used in this investigation.

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# COINCIDENT REMOVAL OF ADDITIONAL STRUCTURES IN RESECTIONS FOR CARCINOMA OF THE COLON AND RECTUM

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DURING RECENT YEARS a rising operability has been reported in carcinoma of the colon and rectum. There is little, if any, indication that this is the result of earlier diagnosis.<sup>5</sup> Rather, it appears to be due to augmented attempts at the removal of growths which previously were considered inoperable. Impulse for such increasing radicalism has been provided by a better understanding of the prevention and control of the several major complications which have attended these operations, primarily shock, infection, and embolism, and by developments in the field of anesthesia particularly the employment of the continuous principle in spinal anesthesia.<sup>3</sup>

Consequently, it is now not unusual for resections of the large bowel to be carried out with palliative intent alone or occasionally to be supplemented by subsequent removal of solitary or grossly localized hepatic metastases.<sup>2, 6</sup> More important, however, has been a trend<sup>1</sup> toward the removal of additional structures or organs adjacent to the primary tumor which are known or considered to be secondarily involved by it in an attempt at cure. A group of such cases forms the basis of the present report.

During the past few years 220 patients with colonic or rectal carcinomas have been seen at this hospital which accepts only indigent patients largely from rural areas.<sup>4</sup> Some idea of the relatively poorer condition of these patients on applying for treatment is evident, in that 86 per cent had lost weight and 67 per cent of these had lost more than 15 pounds. The average duration of symptoms was 18 months. Swinton, reporting from a private urban clinic, found that less than two-thirds of his cases had lost weight and fewer than 50 per cent of these had lost more than 15 pounds. The average duration of symptoms among his patients was nine months.

Specific treatment was not attempted in 31 of the 220 patients, 42 were explored with or without the formation of a colostomy, and resection was carried out in 147 cases, a resectability rate of 78 per cent of all those in whom exploration was considered to be justified, or 67 per cent of all patients seen. Of the first group in which no specific treatment was carried out three patients were resectable but refused operation, four presented extensive post-surgical recurrences, and five were admitted *in extremis* and died before supportive measures could become effective. Eighteen presented clinically obvious distant metastases. A single patient developed a coronary thrombosis while in the hospital and was refused operation on that basis.

Among the 42 patients explored distant intra-abdominal metastases were

## RADICALISM IN CANCER OF INTESTINE

found in 35, a large postsurgical recurrence was found in the pelvis of one, and six presented the combination of far-advanced local disease with marked general debility and were felt to be unsafe for anything but colostomy.

Of the 147 resections, 15 (10 per cent) were operated upon with palliative intent alone, and will, therefore, have no further part in the discussion. One hundred and thirty-two resections (90 per cent) were undertaken with hope of cure. Of these, 13 (10 per cent) were accomplished on patients previously explored at other hospitals, where they had been judged unsuitable for resec-



FIG. 1-A

FIG. 1-B

FIG. 1.—Abdominal wall involvement by carcinoma of the colon.  
A. (Case 6192): Carcinoma of the sigmoid treated two years previously (elsewhere) by Mikulicz resection—recurrent in the implanted bowel and invading the abdominal wall. Treated by Miles' resection in order to accomplish high inferior mesenteric node removal.  
B. (Case 4921): Carcinoma of cecum fungating through abdominal wall postappendectomy, densely adherent to iliacus muscle, removed with abdominal wall, femoral nerve (upper left corner) and iliacus muscle. Abdominal wall following closure consisted of skin lined by omentum.

tion. Excepting for the single above mentioned case with coronary thrombosis no patient was refused operation because of age (10 per cent over 75 years old), diabetes, heart or kidney disease, or general debility, nor was local advancement of the disease by itself a deterrent in any instance. With such a setting it becomes apparent that serious consideration has been given to offering each patient in whom it was not already precluded an opportunity for cure.

In adhering to this principle the removal of some other structure in addition to the bowel was considered necessary in 42 (32 per cent) of the patients

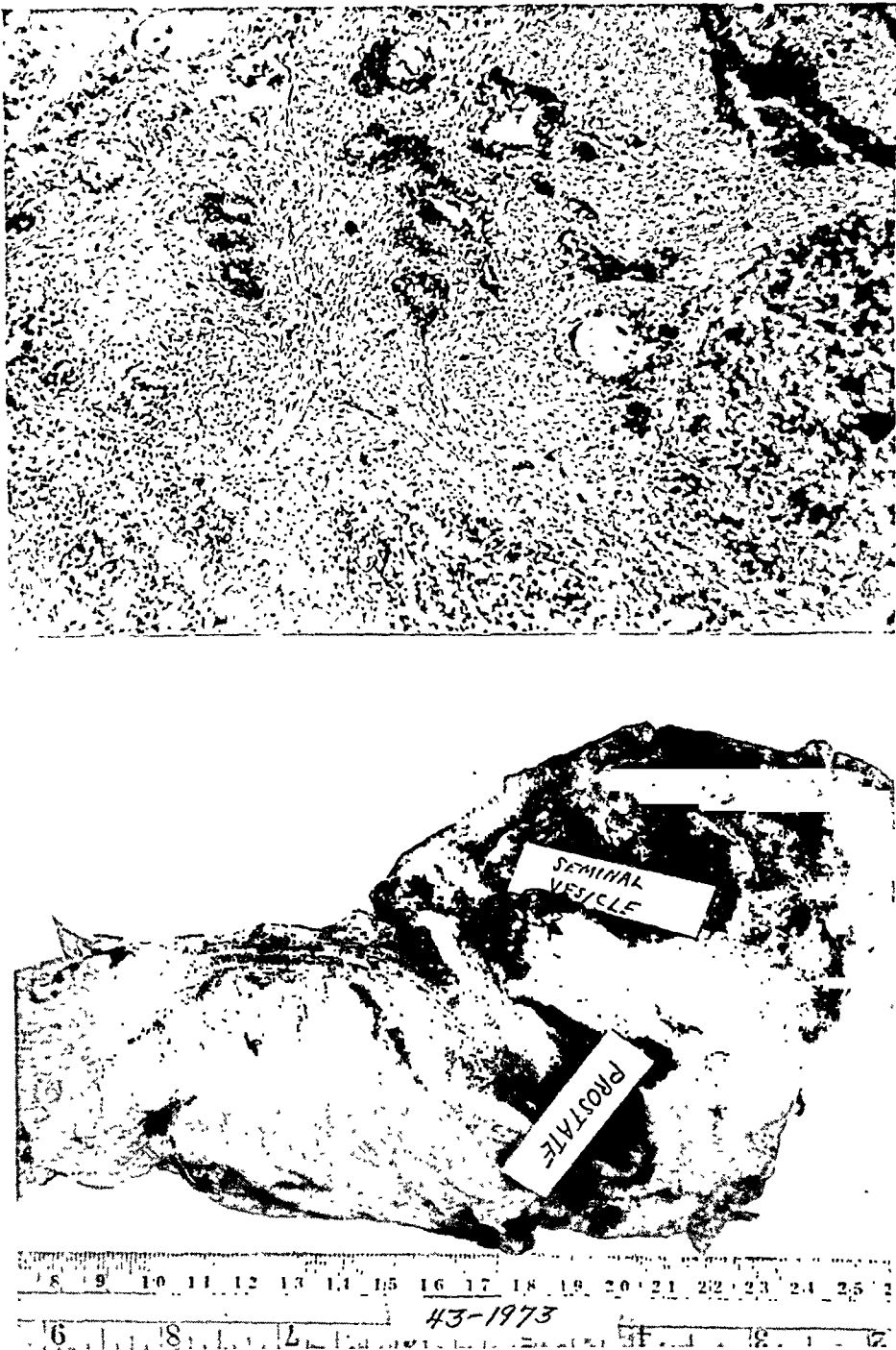


FIG. 2.—(Case 7298) : Involvement of the retro-urethral portion of the prostate by an adjacent carcinoma of the lower rectal ampulla. Photomicrograph shows invasion of the prostate.

resected whose disease, though locally advanced, gave no clinical evidence of having spread beyond the limits of possible surgical removal.

# RADICALISM IN CANCER OF INTESTINE

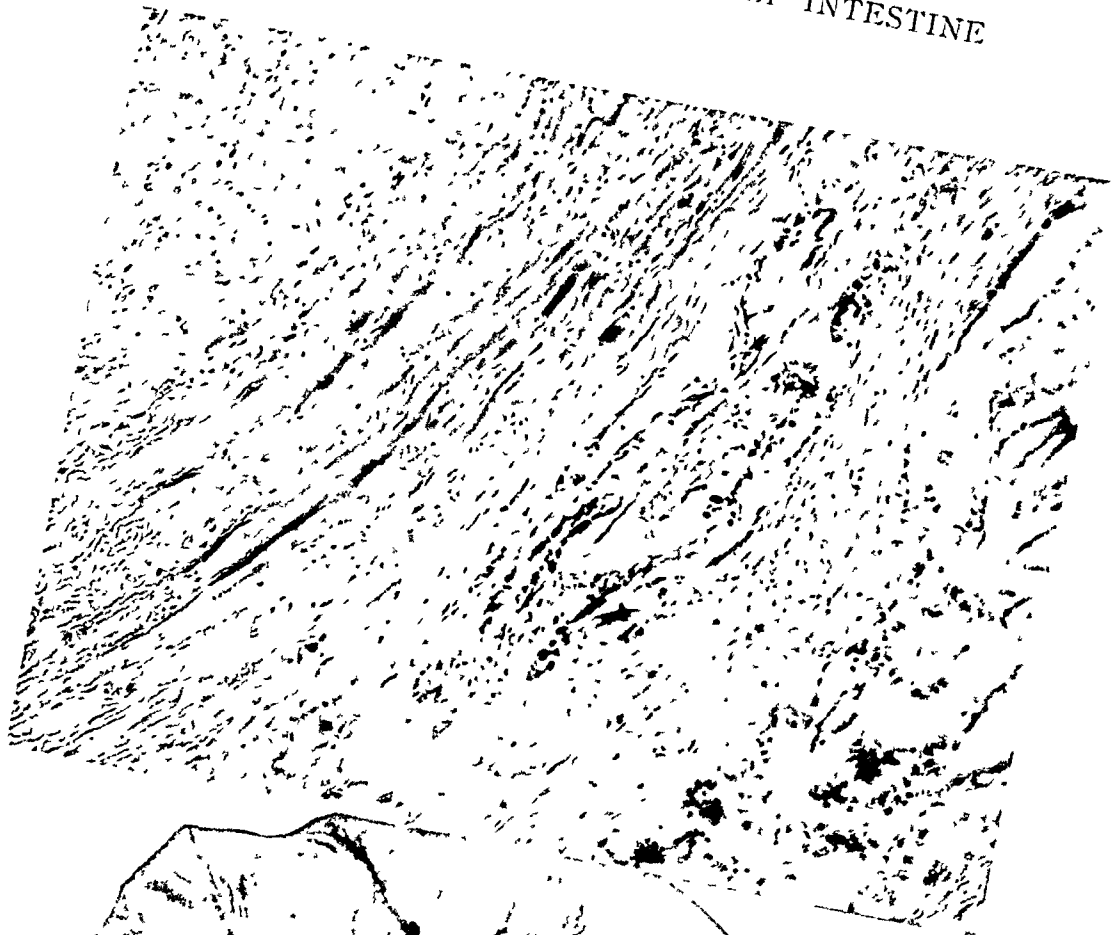


FIG. 3.—(Case 7223): Removal of an adjacent loop of ileum, and encircled segment of ureter, and similarly encircled segments of the external iliac vessels by a carcinoma of the rectosigmoid. Photomicrograph shows involvement of the wall of the external iliac artery.

The single indication for extending the resection in all cases was either known involvement of the structure adjacent to the bowel or such firm fixation to it that dissection between them was felt to entail too great a risk of entering disease. Under certain circumstances wide removal about a point of fixation will not be possible; for example, when invasion has taken place deeply into the lateral pelvic wall. All or part of a single structure was removed in 27 patients, of more than a single structure in 15 patients.

Though the average age of the more radically treated patients was somewhat less than that of those receiving resection of the bowel only, 56 and 61 years, respectively, the much higher incidence of weight loss among the former group, 93 and 68 per cent, respectively, would offer some index as to their

TABLE I

CLINICAL AND PATHOLOGIC COMPARISON OF PATIENTS HAVING RESECTIONS OF THE COLON OR RECTUM ALONE AND THOSE IN WHOM THE RESECTION WAS ATTENDED BY REMOVAL OF ADDITIONAL STRUCTURES

	Clinical			Pathologic*					
	Age	Duration Symptoms	Per Cent with Weight Loss	Opera- tive Mortal- ity	In- volve- ment to Serosa	Lym- phatic Involve- ment	Node Involve- ment (Clearing Method not Used)	Nerve in- volve- ment	Vein In- vasion
Resection of colon and rectum alone (7 pts.) . . . .	61 yrs.	13 mos.	68%	9%	79%	31%	22%	5%	18%
Resection of colon and rectum attended by removal of an additional structure . . . .	56 yrs.	15 mos.	93%	19%	95%†	51%	31%	12%	34%

\* Note: In 41% the sole ominous pathologic feature was involvement of all layers of the bowel.

† In 50% of cases there was actual extension of disease into the additional structure removed.

generally poorer condition and is in part responsible for an operative mortality of 19 per cent as compared to a mortality of 9 per cent where additional procedure was not thought to be necessary. An almost identical duration of symptoms of 15 and 13 months, respectively, in the two groups of patients would indicate that a more aggressive form of disease is the probable basis for the more radical treatment required.

This is borne out in a comparison of those pathologic findings well-known to adversely influence the prognosis in colonic and rectal cancer; namely, involvement of all layers of the bowel, invasion of neighboring lymphatics, vein invasion, nerve involvement and lymph node metastases. All of these were present in higher percentage in those cases where it was necessary to resect some other structure. It should be noted, however, that in 41 per cent no lymphatic or vein invasion, lymph node or nerve involvement was present, the sole ominous feature being involvement of all layers of the bowel wall (Table I). Furthermore, the same could be said of 9 out of 20 cases in which actual gross or microscopically demonstrable invasion of the adjacent structures had already taken place.

# RADICALISM IN CANCER OF INTESTINE

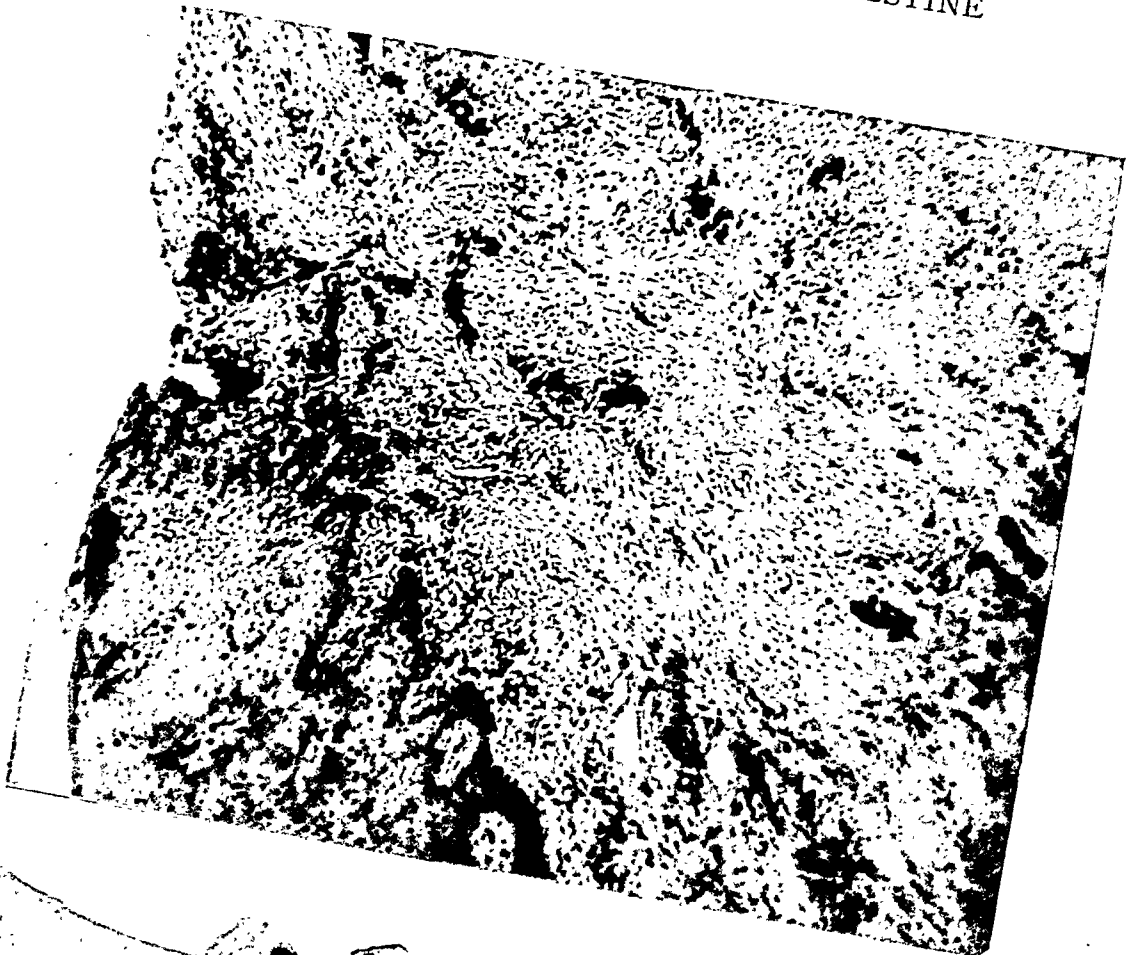


FIG. 4.—(Case 6686): Uterus, tubes, ovaries and entire vagina removed with rectum for an extensive lesion of the latter—shown fungating through the posterior vaginal wall. Photomicrograph indicates the rectal carcinoma ulcerating through the stratified squamous epithelium of the vagina.



Actual involvement of the additional organs removed was demonstrated in 50 per cent of the specimens. It is highly probable that microscopic invasion would have been noted more often if multiple sections had been taken about the point of fixation where a single section failed to demonstrate it. Since involvement of all layers of the bowel was present in all but two cases it is very likely that dissection carried through the usual tissue planes would have resulted in local recurrence in a high percentage of instances in which microscopic involvement of the adjacent structure could not definitely be demonstrated. In only the above mentioned two cases was the fixation on a strictly inflammatory basis. This would strongly suggest that anti-inflammatory roentgenotherapy when administered as a preoperative measure in badly infected lesions should not change the originally indicated extent of procedure even though the amount of fixation might be appreciably lessened.

Among the various structures removed were included a portion or all of the female genital tract in 23 instances, a portion of the male genital tract (prostate and seminal vesicles) in 8, a portion of the bladder or ureter in 5, a segment of small bowel in 4, a sizable portion of the abdominal parietes in 5, a segment of femoral nerve in 1, and the common iliac artery and vein in 1, the external iliac artery and vein in 1, and the common iliac vein alone in 1. These groups are individually too small to make any comparisons as to varying prognosis when one or another structure is involved but it is felt that as larger numbers are reported differences in outlook will become apparent based on differences in the additional lymphatic networks concerned. Our limited experience to date suggests that the ability of the several adjacent anatomic structures to resist invasion by the bowel tumor does vary, however. In eight patients presenting firm fixation to the prostate, actual involvement of that gland was present in only two. It seems likely that the prostatic capsular fascia is largely responsible for this resistance to prostatic invasion. By contrast, successful invasion of the vagina had occurred in 10 out of 16 instances in which it was removed.

Among the 42 cases there were 8 postoperative deaths, an operative mortality of 19 per cent. Of these, 1 occurred as a result of shock, 1 as a result of uremia 4 days postoperative, following resection of a portion of ureter with ligation of its proximal end rather than reimplantation, 1 following a second operation 12 days postresection for the relief of intestinal obstruction, and 1 occurred as a result of necrosing arteritis of the common iliac artery, established at autopsy, 16 days after resection for a lesion complicated by a large lateral pelvic wall abscess. There were two deaths from large pulmonary emboli, confirmed at postmortem examination, 4 days and 3 weeks, respectively, after operation and two deaths from general inanition irremediable by any means with terminal pneumonia 2 and 5 weeks postoperative, respectively. The death from uremia was the only one directly attributable to the extent of the procedure, though there is little doubt but that such extension was a contributing cause in the others.

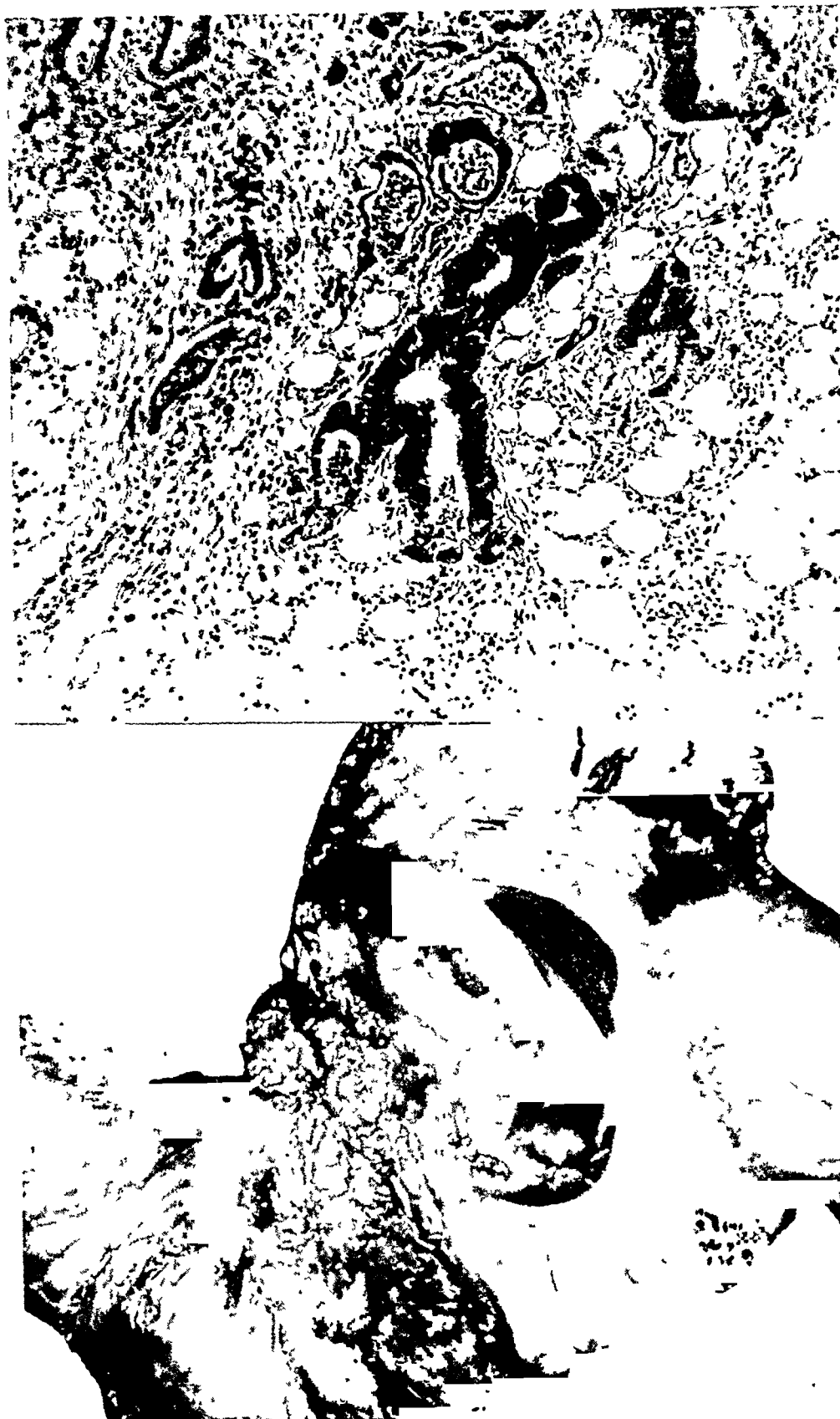


FIG. 5.—(Case 3452) : Uterus, tubes, ovaries and loop of ileum adherent to rectal specimen. Though there was no demonstrable invasion of these structures microscopic invasion of the extracolic fat would indicate the danger of dissecting them off.

TABLE II

TABULATED CASES OF LARGE BOWEL RESECTION ACCOMPANIED BY THE REMOVAL OF ADDITIONAL STRUCTURES

Case No.	Age	Location of Tumor	Operative Procedure	Structures Removed	Demonstrable Involvement of Other Structures	Subsequent Course
1783	69	Lower rectum	Miles' resection	Post. vaginal wall	Positive	Died 22 mos. postop.
2090	34	Lower rectum	Miles' resection	Post. vaginal wall	Positive	Metastases 53 mos. P.O.
2095	45	Rectum	Miles' resection	Post. vaginal wall	Negative	Well 4.5 years
2242	56	Rectum	Miles' resection	Post. vaginal wall	Negative	Recurrence & metas. 43 mos. P.O.
5016	62	Lower rectum	Miles' resection	Post. vaginal wall	Negative	Pulmonary metas. 15 mos. P.O.
5448	61	Rectum	Miles' resection	Post. vaginal wall	Negative	Well 18 mos. P.O.
5854	72	Rectum	Miles' resection	Post. vaginal wall	Negative	P.O. death 2 wks. inanition & pneumonia
5431	69	Low sigmoid	Miles' resection	Left ovary and tube	Negative	Well 1 year P.O.
1828	64	Rectosigmoid	Miles' resection	Cervix	Negative	Died 22 mos. P.O.
2958	55	Rectosigmoid	Miles' resection	Uterus, tubes, ovaries	Negative	P.O. death, shock
3774	31	Rectosigmoid	Two-stage Lahey	Uterus, tubes, ovaries	Negative	Well 3 years
6145	43	Rectosigmoid	Miles' resection	Uterus, tubes, ovaries	Negative	Well 5 months
2688	71	Rectum	Miles' resection	Uterus, tubes, ovaries, post. vaginal wall	Positive	Well 40 months
2811	65	Rectum	Miles' resection	Uterus, tubes, ovaries, post. vaginal wall	Negative	Well 33 months
3056	59	Rectum	Miles' resection	Uterus, tubes, ovaries, post. vaginal wall	Positive	Died 8 months P.O.
3500	65	Rectum	Miles' resection	Uterus, tubes, ovaries, post. vaginal wall	Positive	Well 39 months
5849	17	Rectum	Miles' resection	Uterus, entire vagina	Positive	Recurrence 13 months
6173	67	Rectum	Miles' resection	Uterus, tubes, ovaries, entire vagina	Positive	Recurrence 13 months
6686	62	Rectum	Miles' resection	Uterus, tubes, ovaries, entire vagina	Positive	Well 8 months
6715	37	Rectum	Miles' resection	Uterus, tubes, ovaries, entire vagina	Positive	Well 7 months
504	57	Rectum	Miles' resection	Retrourethral prostate and seminal vesicles	Negative	Well 52 months
1670	66	Rectum	Miles' resection	Retrourethral prostate and seminal vesicles	Negative	Suicide 10 months
2252	34	Rectum	Miles' resection	Retrourethral prostate and seminal vesicles	Negative	Died of disease 33 mos.
2534	61	Rectum	Miles' resection	Retrourethral prostate and seminal vesicles	Positive	P.O. death 12 days, intestinal obstruction
3102	68	Rectum	Miles' resection	Retrourethral prostate and seminal vesicles	Negative	Died 3 months
3582	58	Rectum	Miles' resection	Retrourethral prostate and seminal vesicles	Negative	Died 7 months
5865	50	Rectum	Miles' resection	Retrourethral prostate and seminal vesicles	Negative	Well 17 months
7298	63	Rectum	Miles' resection	Retrourethral prostate and seminal vesicles	Positive	Well 2 months
3296	55	Sigmoid	Resection— anastomosis	Posterolateral bladder wall + common iliac vein	Positive	Died of recurrence 39 mos. P.O.
3751	45	Rectosigmoid	Miles' resection	Entire post. bladder wall	Negative	Died of recurrence 8 mos. P.O.
5498	70	Rectosigmoid	Two-stage Lahey	Entire post. bladder wall	Positive	Well 18 months later
2579	58	Low sigmoid	Resection— anastomosis	Segment of ileum, left tube and ovary	Positive	P.O. death, uremia
3019	48	Rectosigmoid	Miles' resection	Segment of ileum	Positive	P.O. death (embolus)
3452	48	Rectosigmoid	Miles' resection	Segment of ileum, uterus, tubes, ovaries	Negative	Alive and well 3.5 years later

# RADICALISM IN CANCER OF INTESTINE

TABLE II (Continued)

Case No.	Age	Location of Tumor	Operative Procedure	Structures Removed	Demonstrable Involvement of Other Structures	Subsequent Course
7207	59	Low sigmoid	Hartman resection	Segment of ileum and bladder	Positive	P.O. death 2 wks.—wound hemorrhage
7223	59	Cecum	Right colectomy (Mikulicz)	Right ext. iliac artery & vein + segment right ureter	Positive	P.O. death (embolus) 3 weeks
2023	78	Cecum	Right colectomy with anastomosis	Large area ant. abdominal wall	Positive	P.O. death 5 wks. inanition
3135'	58	Right colon	Right colectomy with anastomosis	Iliopsoas muscle (entire)	Negative	Died 23 months later
4921	55	Right colon	Right colectomy (Mikulicz)	Large segment ant. abdominal wall + iliac muscle + femoral nerve	Positive	Well 28 months
5022	68	Splenic flexure	Resection	Entire wall to skin	Negative	Well 24 months
6192	72	Sigmoid (recurrent)	Miles' resection	Large area of anterior abdominal wall	Positive	Well 1 year later
7744	72	Rectum	Miles' resection	Posterior vaginal wall	Positive	Very recent

Fifteen patients are dead of, or are living with, recurrent or metastatic disease. The remaining 19 are alive and apparently well. Two of these have lived from 4 to 5 years, four from 3 to 4 years, three from 2 to 3 years, five from 1 to 2 years and five less than one year since operation.

COMMENT: That these extensive procedures are worth while is attested to by the fact that evidence of spread beyond the local lesion was absent in 41 per cent of cases and that a fair number of these patients have already survived for considerable periods. It is hoped that additional reports of similar series of cases will be forthcoming so that as the numbers increase a better appraisal of these extended resections may be obtained than is at present available, first regarding the entire group and second regarding the resection of the individual structures above mentioned. For example, it is suggested that coincident resection of abdominal wall or vagina will prove to be far more advantageous than removal of iliac vessels or the bladder. Involvement to the serosa in 79 per cent of patients in whom resection of the bowel alone was accomplished suggests the advisability of resecting adjacent attached structures more frequently with less indication than marked fixation to them as has usually been true in the past. It is conceivable that more cures will result from such a course than from resecting adjacent organs in which direct invasion is demonstrable. The treatment of cancer of the colon and rectum has been considerably clarified in recent years.<sup>1</sup> The justification of and indications for the coincident removal of additional structures remains, however, as one of the unsolved aspects of the problem in which further enlightenment is needed.

## SUMMARY

(1) As a result of a tendency toward increasing radicalism in dealing with carcinomas of the large bowel, more frequent attempts are being made to remove tumors which are definitely, or are suspected of invading adjacent structures.

(2) Forty-two such cases in which additional organs were removed in order to accomplish removal of a rectal or colonic cancer are presented.

(3) The poorer general condition of these patients, as well as the increased extent of the operations, as compared to the usual types of colon resection is reflected in an appreciably higher operative mortality.

(4) Justification for such procedures is indicated by the fact that apart from involvement of all layers of the bowel wall, other unfavorable pathologic signs were absent in 41 per cent of the cases and by the fact that 19 of 34 patients surviving operation are still living for considerable periods.

(5) It is suggested that the reporting of more such cases will contribute to a much needed clarification of the indications for these extended resections.

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## CHOLEDOCHUS CYST

LT. COL. EDWARD F. McLAUGHLIN, M.C., A.U.S.

A CASE OF CHOLEDOCHUS CYST is presented differing in certain aspects from others already reported; the diagnosis was arrived at preoperatively (as nearly as that is possible in such an obscure condition) and the operative treatment included some steps which had not been previously employed.

Choledochus cyst is an interesting condition, both from the pathologic and clinical standpoints. Judd and Green,<sup>1</sup> at the Mayo Clinic, demonstrated its rarity when they reported finding but one case out of 17,381 in a review of the records of operations upon the biliary system for a 20-year period. Smith,<sup>2</sup> in searching through the records of the Presbyterian Hospital, in New York City, covered 757,000 and found but two cases. The total number of reported cases as given in articles which contain a review of the literature on the subject varies somewhat according to the authors' interpretations of what cases should be included. Smith,<sup>2</sup> for instance, collected 181 cases while Shallow, Egger, and Wagoner,<sup>3</sup> in an article a year later, were able to find but 175. The total probably is under 200. Vinninger and Cash<sup>4</sup> covered the subject very thoroughly and their article, though written in 1932, is still regarded as an excellent reference. It contained one of the first reviews of the literature on choledochus cyst and goes into etiology, pathology, etc., very systematically.

As to *etiology*, the consensus of opinion both from this and from other articles, seems to be that in the case of a true cyst of this type, the condition is one of congenital maldevelopment of the common bile duct. For a meticulous description of the relevant normal and pathologic embryology, one can find none better than that given by Swartley and Weeder<sup>5</sup> in a paper primarily concerned with the reporting of an extremely unusual form of this rare condition, "choledochus cyst with a double common bile duct." In subsequent writings on this same case, Weeder,<sup>6</sup> and Swartley<sup>7</sup> make further pertinent observations on the embryology. Among the things which bring on trouble probably are the possible "exciting" factors which precipitate symptoms in an anomaly presumably present since birth. The thing which brings on trouble probably varies in each individual case. Obstruction, partial or complete, is nearly always the mechanism responsible for the onset of difficulties. Trauma and inflammation must be seriously considered as exciting factors. Disproportionate growth of one part of the altered biliary system in relation to another may in time result in torsion and narrowing of the passageways. But it is almost impossible in most instances to tell what has changed a silent lesion of this sort into an active one.

The condition is said to occur more often in the female than in the male, and more often in children than in adults.

A triad of *signs and symptoms* seems to have been noted repeatedly enough in the various studies to be called the usual clinical picture. These are (1) abdominal pain; (2) tumor mass; and (3) jaundice. Roentgenologic studies

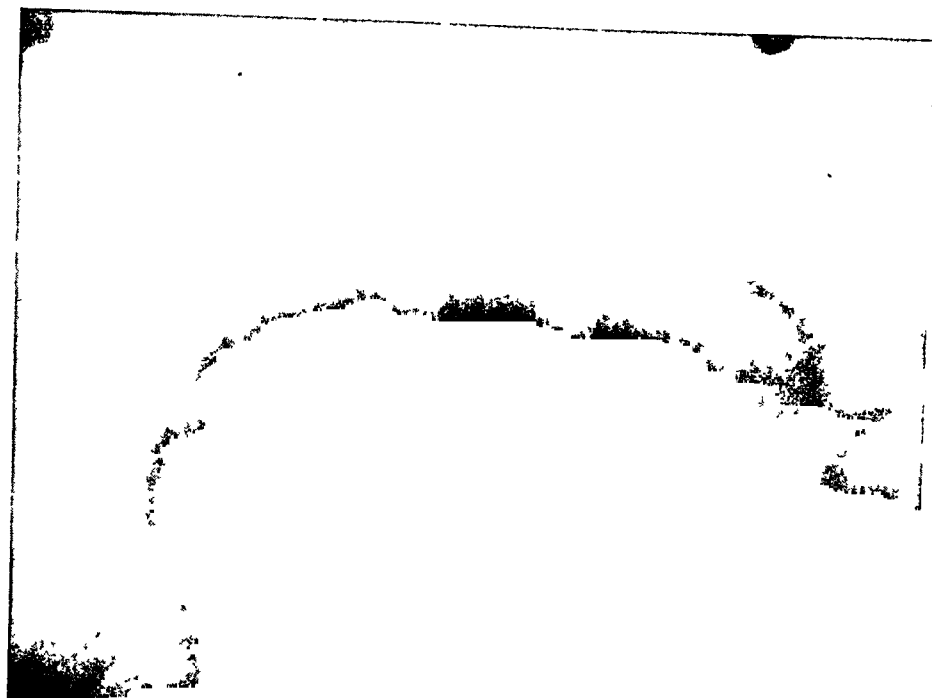


FIG. 1.—Plain film of the abdomen: Patient lies on his back. The mass is seen to occupy most of the right side of the abdomen. In this position, the fluid is posterior and the gas has risen to the anterior portion of the cyst, therefore, the shadow seen in the picture is cast by the overlying gas.



FIG. 2.—Plain film taken of the patient in the upright position shows the outline of the upper portion of the cyst. A fluid level is clearly demonstrated and the gas above it also evident. A second and smaller collection of gas is seen above the dome of the cyst and toward the midline.

## CHOLEDOCHUS CYST

probably contribute more accurate information than any other artificial aid. Liver function studies sometimes are of value, and tests for jaundice are at times a definite help.

As to the *course*, it is conceivable that some choledochus cysts never have given trouble. Once blockage has occurred, however, the course is progressively downgrade and death eventually ensues. If the obstruction is acute or relatively so, cyst rupture and peritonitis may kill the patient; if less acute, high

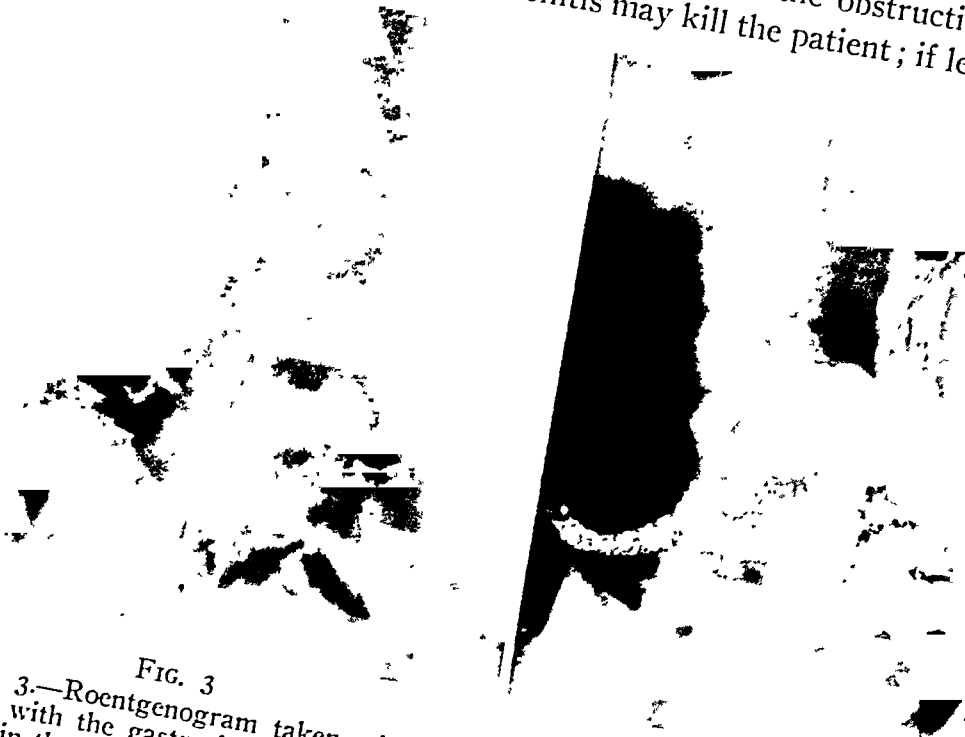


FIG. 3

FIG. 4

FIG. 3.—Roentgenogram taken with the patient in the upright position and in conjunction with the gastro-intestinal study. In this film, the fluid level and the overlying gas within the cyst is again demonstrated. The small separate collection of gas is noted just above the dome of the cyst as in Fig. 2; however, in this film, the barium demonstrates the location of the transverse colon and eliminates gas in this structure as accounting for the shadow above the cystic mass.

FIG. 4.—Roentgenogram demonstrates the shadow of the gas in the top of the cyst plus the small gas shadow just above the cyst, and the outline of the stomach, duodenum and jejunum. The position of the stomach and the small bowel in relation to the gas shadow superior to the dome of the cyst clearly demonstrates that this collection of gas is not one in an overlying portion of the gastro-intestinal tract. Furthermore, its constancy in varied stages of the gastro-intestinal study also tend to establish it as being contained in a fixed structure in that region. This film also shows how the cyst has stretched out the second and third portions of the duodenum. Apparently, part of the cyst has insinuated itself within the duodenal loop.

intestinal obstruction or a progressive obstructive jaundice with liver damage and general toxemia may be the direct causes of death. Should the disease be a prolonged one and the interference with bile flow incomplete, it is conceivable that changes of the type seen in biliary cirrhosis could take place in the liver with secondary enlargement of the spleen. This was the observed succession of events in one case where a second operation and later an autopsy permitted a direct check on the progress of the disease. The case was atypical, the cyst involving the right of two "common bile ducts." The cystic right duct drained the right hepatic lobe; the other, the left. The right duct was completely extirpated and successively a shrinkage of the right lobe of the liver with compensatory enlargement of the left lobe and a subsequent enlargement of the



spleen took place. The patient developed a thrombocytopenia and died after many hemorrhages. Section of the right lobe of the liver showed changes suggestive of cirrhosis. The whole clinical picture resembled an induced Banti's disease. (Case of Swartley and Weeder,<sup>6</sup> with an interesting discussion by Dr. Allen O. Whipple.)



FIG. 5.—A roentgenogram which resolves the question as to where the duodenum runs in relation to the cyst. The course of the barium from the pylorus is downward and forward, so that the duodenum may be said to be displaced forward by the mass and to lie anterior to it. This picture is taken transversely. The stomach can be seen in somewhat hour-glass shape, the barium narrowing down in the center and widening out superiorly and inferiorly. Beyond the stomach, the dome of the cyst filled with air is visible and the fluid level is again noted.

*Treatment* is obviously surgical, and has not been too successful. In a series of cases reviewed by Shallow, Egger, and Wagoner, the over-all mortality was 58 per cent. Primary anastomosis of the biliary and intestinal tracts gave a mortality of 27 per cent, simple drainage of the cyst, a mortality of 88 per cent, and if the condition was recognized and no operation undertaken, a 100 per cent fatality. Ladd and Gross<sup>8</sup> are somewhat more optimistic about the results of direct anastomosis between the biliary tract and intestine; reporting but a 9 per cent mortality, though the general mortality for cases treated by various methods in their series was 69 per cent.

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**Case Report.**—A colored male, age 22, was admitted, 23 November, 1944, with the chief complaint that he was "not able to eat as much" because of a "knot" in the upper right side of his abdomen. This had been noted during the past five months, prior to that he had been well and had served for one and one-half years in the Army, doing regular duty. The symptoms were actually a soreness and a fullness after meals, felt in the

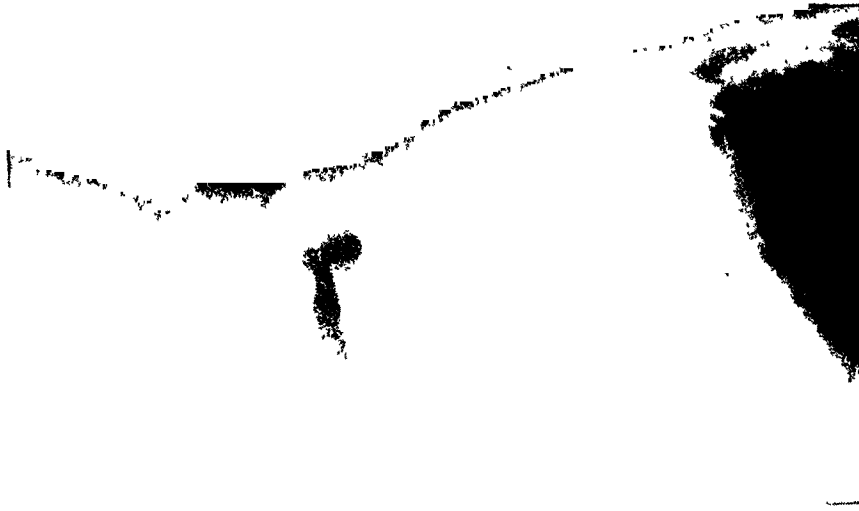


FIG. 6



FIG. 7

FIG. 6.—A roentgenogram which contributes further to the outlining of the mass. Patient is lying on the abdomen and the film is taken transversely. The enclosed air again rises, and what is actually the posterior portion of the cyst is now clearly demonstrated.

FIG. 7.—With the patient lying on the left side an A.P. view was taken, and demonstrated the outline of the cyst further. Lateral portion of it is now filled with the gas which has risen; the central portion of the cyst is filled with fluid and does not show up.

epigastrium and, while his appetite continued good, he could not eat as much as he wanted to because of the distress which came on after ingesting a small quantity of food; as this grew worse, he cut down more and more on the quantity and finally began to skip meals. As a result, he lost 25 pounds in weight, most of it in the two months immediately prior to admission. As this postprandial distress became worse, especially once after a session on the obstacle course, the soldier went on sick call a few times, and one week before his hospitalization was admitted to another Army hospital where studies were made, and a cystic mass in the upper right quadrant was demonstrated roentgenographically.

The patient had been a farmer in Tennessee before coming into the Army, and had had no service out of this country. He drank moderately. His father, mother and sis-

ter were all living and well. As a child, he had had measles and chicken pox and, at 16 years of age, had fractured his left ankle. Syphilis was denied but he had been getting weekly injections for some unknown condition. One year ago, he had had gonorrheal infection.



FIG. 8

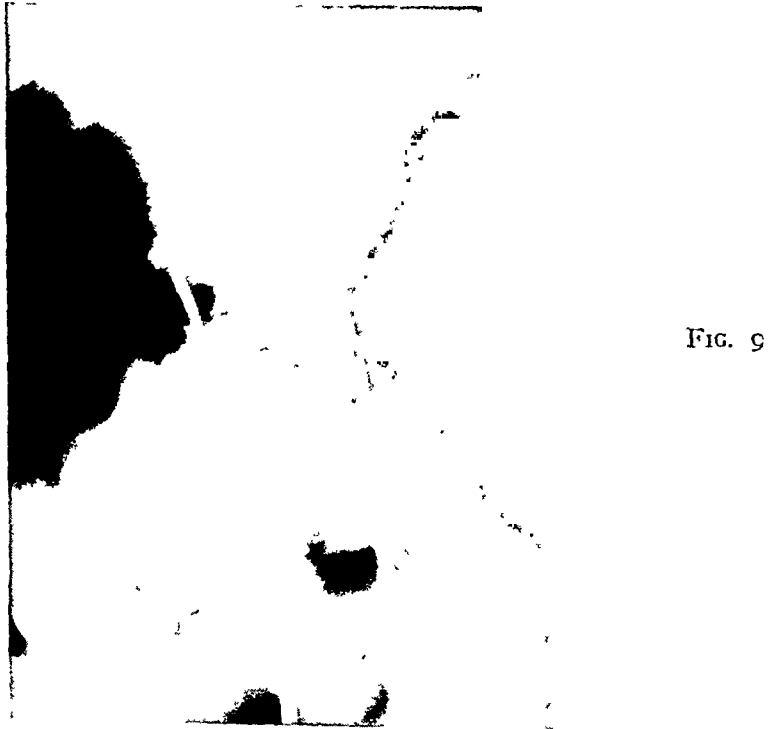


FIG. 9

FIG. 8.—Patient lying on right side, the inner contour of cyst is shown by the bubble of enclosed gas which, again, has risen to the uppermost portion of the cyst. This film, plus the foregoing films taken in other positions, demonstrate the cystic mass to be elliptical in outline in the vertical plane. Its walls, apparently, are rather firm or, at least, fixed to adjacent structures, since in none of the different positions is it seen to be collapsed even partially.

FIG. 9.—Retrograde pyelograms show normal kidney, pelvis and ureter outlines on both sides. The mass does not seem to impinge upon the kidney or on the urinary tract, nor does it seem to be a part of either.

*Physical Examination:* A tall, lanky, young Negro was encountered who looked a bit "draggy," and showed that he had lost weight. No jaundice was noted. The various parts of the body were carefully checked and were found to be within normal limits, except for the abdomen. Here, a "fullness in the right upper quadrant extending to the

midline and to about five finger's breadth below the costal margin" was noted. The mass was described, both as "doughy" and "cystic" to palpation, and was tender. No other masses or tender areas were found.

*Laboratory studies* showed the following:

1. Blood counts. These varied rather widely when taken on three occasions, with a two-week period, therefore, each report is given:

- a. R.B.C. 5,200,000, Hb. 15.9 Gm.; (101%); W.B.C. 6,400, P. 19%, L. 72%, M. 9%, E. 2%.
- b. R.B.C. 4,420,000, Hb. 12.5 Gm.; W.B.C. 5,000, P. 37%, L. 63%, MCV. 73, MCH. 29, MCC. 39.
- c. R.B.C. 5,450,000, Hb. 11.5 Gm.; W.B.C. 20,600, P. 91, L. 9.



FIG. 10.—Barium meal given one month postoperatively shows the absence of the cystic mass, and a flattening all along the upper part of the duodenum where anastomosis between the dome of the cyst and this part of the bowel had been effected. Absence of gas in the gall-bladder is noted, and it is also noteworthy that the barium does not extend up the cystic duct or the common hepatic duct.

2. Clotting time 7 minutes, 15 seconds
3. Urine: Yellow, cloudy, sp. gr. 1021, acid, albumen plus two, sugar 0. Negative for pus, blood or casts.
4. Icteric index 5.
5. Kahn, negative.
6. Heterophile antibody, negative.

7. Serum amylase 81 mg. per 100 cc. of reducing substance, produced by the enzyme (Zomogi).

8. Stool for parasites and ova, none seen.

9. Prothrombin time 114 per cent of normal.

10. Blood type—A.

*Röntgenologic studies* demonstrated the following (see Figs. 1 to 10):

1. 18 November, 1944: "large ovoid mass, right upper quadrant displacing the hepatic flexure caudally."

2. 18 November, 1944: "ovoid cystic mass containing about one-third gas in the right upper quadrant below the liver. Gas-containing small bowel anterior to the mass may represent duodenum. *Irregular gas pockets superior to the mass represents an extension from the tumor.* Nonfunctioning gallbladder. Fluoroscopy of the stomach and small intestine demonstrates an enlargement of the duodenal curve, which is displaced anteriorly. Large pancreatic cyst arising from the head of the pancreas."

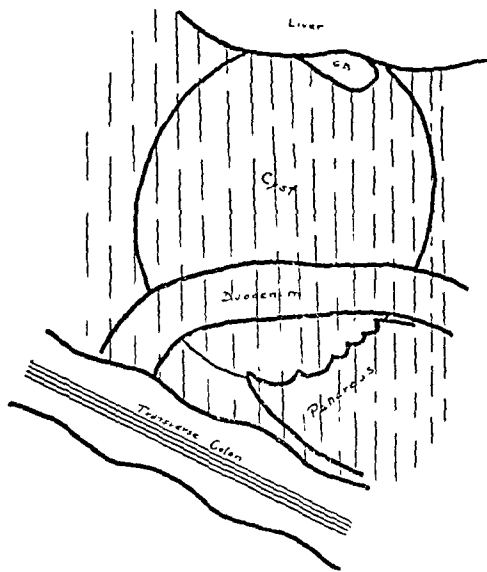


FIG. 11.—This illustration demonstrates the situation as it was encountered upon opening the abdomen. A veil of transparent and translucent peritoneum like tissue extended from under the liver margin down to the transverse colon. Beneath it, a tense cystic mass was visible and palpable. On the anterior surface of this mass, a segment of intestine, later identified as the duodenum, was found coursing downward and outward. From under the liver margin, the fundus of the gallbladder protruded and was not covered by any veil. It was filled with gas. The pancreas occupied a position under the veil and within the curve of the duodenum closely adherent to the inner lower wall of the cyst and represented in the illustration by the irregular line depicting the way in which the head was cupped about the internal portion of the cyst wall.

section, freeing of the cyst was begun. During the freeing process, the head of the pancreas was identified as cupping about the left side of the mass. There was a "pedicle" two centimeters in length, later shown to be the lower portion of the common

3. 21 November, 1944: "normal intravenous urograms, calices are only fractionally visualized on the left. Portion of the ureter between the second and third lumbar vertebra on the right fails to fill as the result of pressure from the extrinsic mass. Stereo film demonstrates right kidney to be in the usual position posteriorly."

4. 25 November, 1944: "same large mass in the right side of the abdominal cavity is evidently still present. This contains a large amount of fluid and also a considerable quantity of gas, so that the fluid level is easily made out in both upright and horizontal positions. Impression deferred. Further studies indicated."

5. 25 November, 1944: "further films show the same large mass in the right side of the abdominal cavity, containing a large quantity of gas, and a large amount of fluid."

6. 28 November, 1944: "the retrograde study with cystoscopy and catheterization of both ureters, showed essentially normal appearing calices and renal pelves. There was no evidence of any connection between the upper urinary tract and the large cystic mass on the right upper and middle quadrant."

*Operation.*—29 November, 1944: The abdomen was opened through a high right rectus incision. A large cystic mass was immediately apparent in the upper right quadrant, covered with a veil of peritoneum-like tissue (Fig. 11). It was impossible to clearly identify it immediately. A loop of small bowel crossed the anterior surface of the cyst diagonally from the above downward and from left to right, also under the veil—it was duodenum. Other organs in the abdomen were normal. The veil was split, and by blunt and sharp dis-

## CHOLEDOCHUS CYST

duct running between the lower portion of the cyst and the second portion of the duodenum. The cyst wall was punctured near the lower pole and clear light bile exuded. Yellow bile and "mud" were also seen within. Aspiration netted about 1000 cc. of chalky-yellow material and light bile. The lower end of the cyst was detached, and the main mass freed upward. The duct entering the duodenum was probed found to be a true duct, and then clamped. The duct was later inverted into the wall of the duodenum, and the peritoneum plicated over it. Separation to the left, from the head of the pancreas was accomplished without difficulty. At the top, the gallbladder was seen protruding between the dome of the cyst and the edge of the liver uncovered by any membrane. It was bluish-white, pale, translucent, and filled with gas. It could be squeezed and emptied of its gas like a small balloon, and would refill on releasing pressure. Further freeing of the cyst exposed the structures above—the cystic duct and the common hepatic duct. These were normal in appearance and arrangement. They entered the dome of the cyst separately (Fig. 12). (It is well to pause and remark that up to this point what was being done was in effect an intra-abdominal, operative, differential diagnosis. One does not simply enter the abdomen and immediately identify a choledochus cyst or a pancreatic cyst or any other of the more obscure cysts or tumors.)

A small portion of the dome into which the ducts entered was left and the rest of the cyst cut away. This small dome was then anastomosed to the duodenum (Fig. 13). A cigarette drain was inserted to the operative field, and the abdomen was closed in layers.

*Postoperatively*, the patient's course was not eventful. He had a postoperative anemia which responded to transfusion. For a few days he was jaundiced. On the third postoperative day, his icteric index was 25 and on the sixth postoperative day, it had come down to 13. He never did have clay-colored stools, however. There was no bile drainage from the wound. The cigarette drain was removed on the fourth postoperative day and the sutures were removed, and the wound healed on the ninth day. The patient was up on the fourteenth day. After that, he ate regular diet, gained weight and continued to have formed stools of normal color. He had had a little transient diarrhea on his third and fourth days.

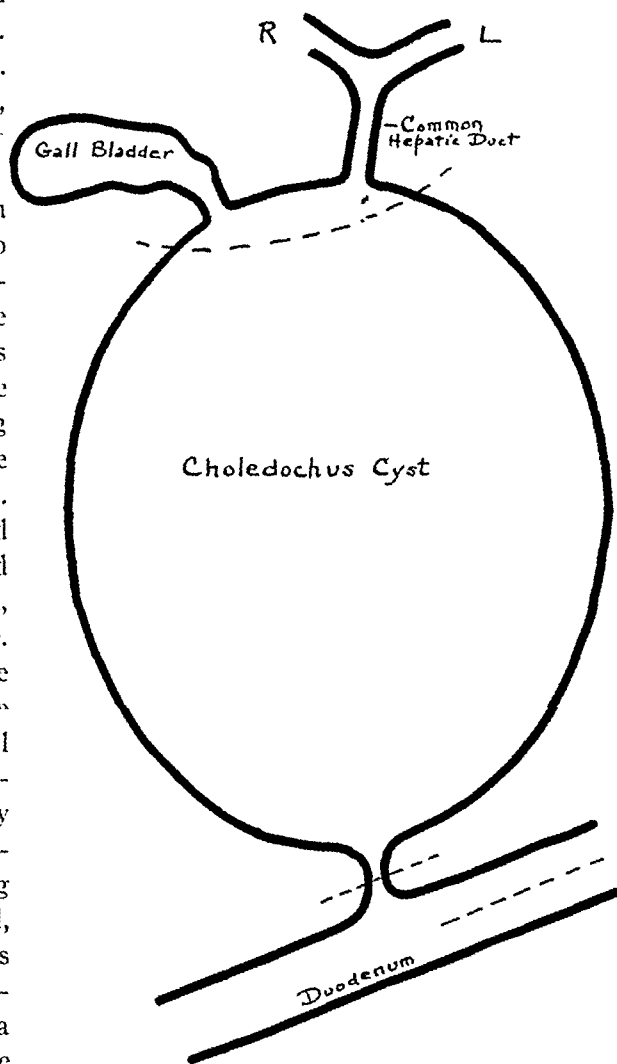


FIG. 12.—This illustration shows the arrangement after dissection. The gallbladder above connects directly with the cyst through its cystic duct. The common hepatic duct communicates directly with the cyst and from it branch off the right hepatic duct and the left hepatic duct. The cyst, itself, was found to communicate directly with the duodenum at its lower end through a patulous duct of about 7.5 millimeters external diameter. The dotted lines show from above downward the site at which the cyst was severed from its own dome. The point at which the duct leading from the cyst to the duodenum was severed is indicated as is also the line of incision on the duodenum where the anastomosis between the cyst dome and that structure was effected.

It was not possible to demonstrate the gallbladder by the usual dye technic one month after operation. Roentgenograms of the G.I. tract showed the duodenum well outlined, and there was no extension of the barium into the biliary system. Seventy-nine days after admission, the man was discharged to duty, having gained approximately 25 pounds during his hospital stay.

The pathologic examination of the cyst wall showed it to be mostly fibrous tissue without a lining epithelium but with some duct-like structures in part of the wall (Figs. 14, 15 and 16).

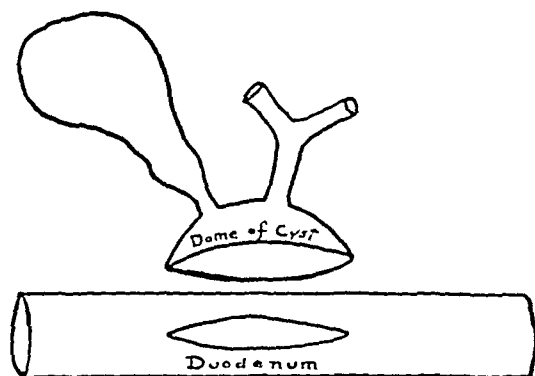


FIG. 13.—Shows the type of anastomosis undertaken in this case. A small cap of the dome of the cyst was allowed to remain and this was joined to the duodenum. Leading into this cap are shown the cystic duct from the gallbladder and the common hepatic duct.

DISCUSSION.—It is almost an impossibility to make an absolute diagnosis of a choledochus cyst pre-operatively. In the present instance, it headed a list of diagnoses, including pancreatic cyst, retroperitoneal cyst, liver cyst, *etc.*, and was given by the operator as his preoperative preference. After all, as Swartley emphasizes, it is the preoperative suspicion of the presence of a choledochus cyst that makes dealing with it in the abdomen more effective, lessens mortality and improves results. From a purely statistical standpoint this patient should not have been one

to excite suspicion that he was afflicted with a choledochus cyst—he was an adult, not a child, male not female, and of a race in which the lesion has not often been found. Of the three “pathognomonic” signs of choledochus cyst—pain, tumor mass and jaundice—two were definitely present. The patient had distressing pains and he had the tumor mass. Jaundice was absent both clinically and by laboratory determination. The roentgenograms were of greatest help, for they confirmed the presence of the mass, showed it to be cystic and showed that it contained gas. The inability to demonstrate a normal gallbladder in a young man, age 22, suggested involvement of the biliary tract. Taking the pictures with the patient in various positions was extremely helpful in outlining the walls of the mass and in showing something of the nature of these walls—the failure to collapse in various positions for instance. Identification of the air within the cyst was of significance, and the fluid level indicated the presence and amount of liquid within it. The gas in the gallbladder is visible in the films and, as described by the roentgenologist, “seemed to emerge from part of the tumor.” Its full significance was not appreciated before the abdomen was opened. It should be looked for in future cases, and may be regarded as a finding of utmost value. Being isolated so exactly in the different views, it obviously was not gas within loops of the bowel itself; its constancy of position precluded its being free air under the diaphragm. The logical inference is that the gas in the cyst and that trapped in the gallbladder came from the intestinal tract *via* the communication between

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the cyst and the duodenum. Fluoroscopy in which the duodenum was demonstrated as crossing in front of the cyst, was extremely valuable, and the roentgenograms showing the stomach from the side, with barium in it and the barium continuing down in the duodenum in front of the cystic mass, is also of value. Of diagnostic value from the negative standpoint, was the fact that the gastro-intestinal tract appeared normal—the cystic mass not arising from a part of the intestine. The normal urinary tract visualization had a similar

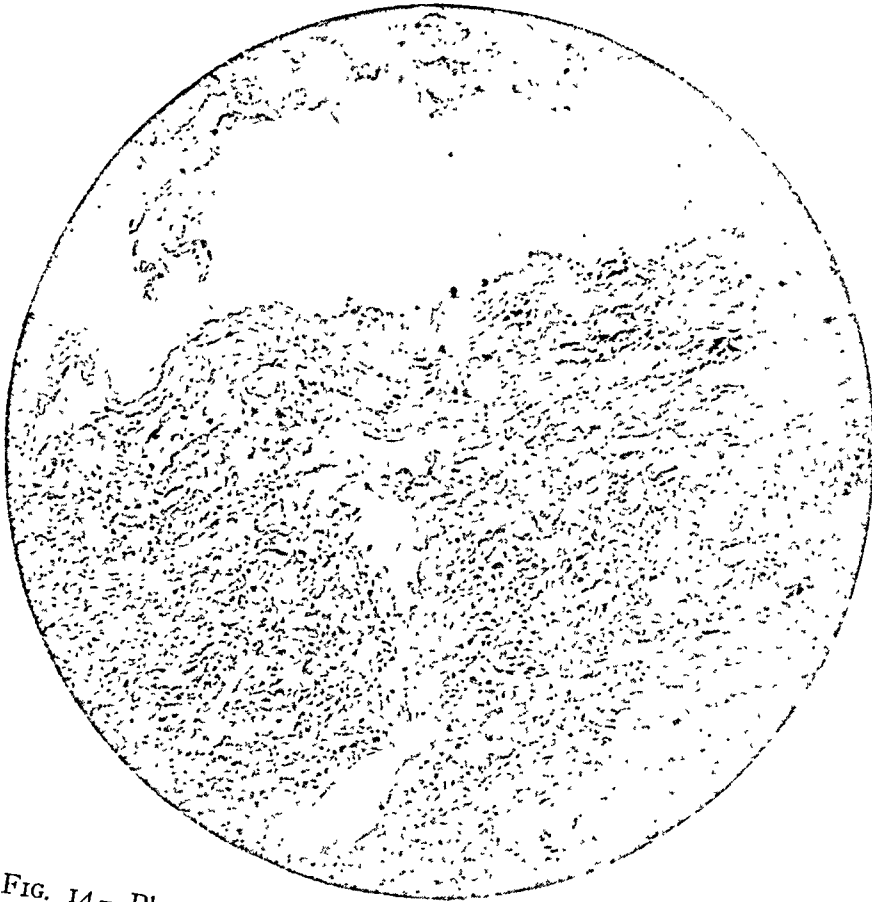


FIG. 14.—Photomicrogram showing: "No specific living cells are noted on the free surface, and the free surface has poor staining characteristics, suggesting early stages of necrosis." The section shows what is usually seen in sections of these walls—the absence of a living epithelium.

value in eliminating, almost completely, the possibility of the mass being a kidney lesion. Laboratory studies were of little value; the confusing picture from the blood count was not of help. The leukopenia apparently was fairly constant and perhaps it was some inflammatory change which elevated the leukocyte count and called for the numerous polymorphonuclear cells reported in the examination immediately before surgery.

The most plausible diagnostic possibilities, other than choledochus cyst, were pancreatic cyst, solitary cyst of the kidney, hepatic cyst and "retroperitoneal" cyst.



Pancreatic cyst could not be ruled out, but such cysts are usually not so completely and so far to the right. If they extend to the right there is usually a goodly portion still in the middle or even to the left. The ordinary pancreatic cyst is not gas-containing. The findings of a normal serum amylase meant little.

Solitary cyst of the kidney, which can closely resemble the size and situation of a choledochus cyst such as this one, was pretty well eliminated by the normal urograms. These cysts usually displace the kidney and distort the shadows of the calices. Also they rarely contain gas (See Fig. 17).

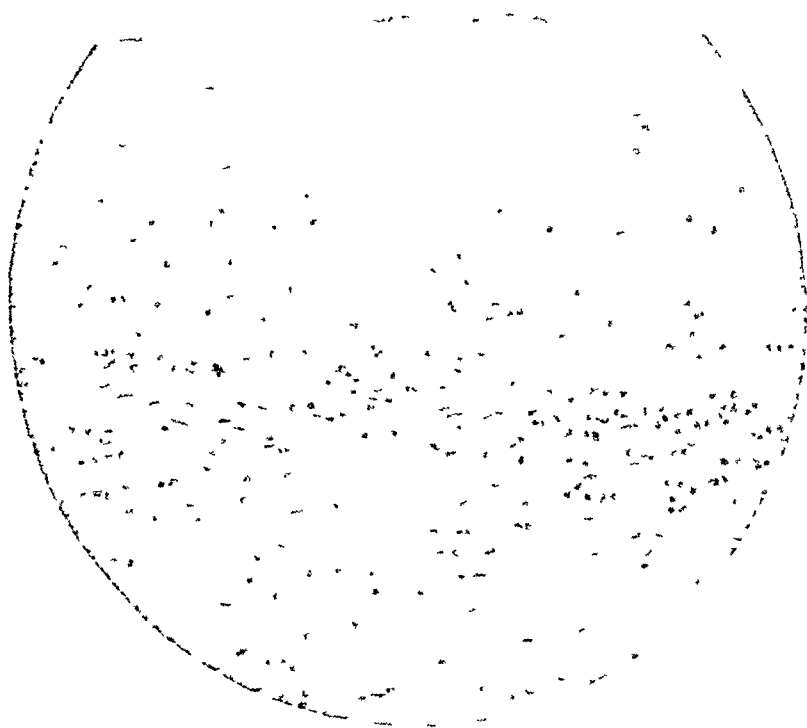


FIG. 15—Photomicrogram showing. "The entire wall is of considerable thickness and is composed of parallel and interlacing fibers of coarse connective tissue. Between these fibers are numerous nests of chronic inflammatory cells and many capillary-size blood vessels"

This section shows well the nondescript fibrous tissue make-up of the thick wall of these cysts.

Echinococcus cyst of the liver was not completely ruled out by the absence of parasites and ova in the stools. The absence of eosinophils in two of three preoperative differential white cell counts, and the presence of but 2 per cent in the third, is of more weight. Calcium is sometimes seen in the walls of an echinococcus cyst, especially the older ones, and at times daughter cysts can be made out; such was not the case here.

"Retroperitoneal cysts" or cystic tumors or "reduplication of the gastroin-

## CHOLEDOCHUS CYST

testinal tract" (Ladd) may mimic any of the other unusual lesions; they could not be completely ruled out in this patient. Some of this group arise along the base of the mesentery and occupy approximately a midabdominal position. Omental cysts are more moveable than the intestine, as "massive diverticula" "reduplications" arising directly from the cyst walls may be less thick and firm than those in contain gas, and in these the walls may be demonstrated in the present case. Roentgenologic studies of the whole gastro-intestinal tract showed no peregrinations of the barium into the mass in question.



FIG. 16.—Photomicrogram showing: "At one edge of the section, small glandular spaces are noted lined by medium, tall, pale columnar epithelial cells somewhat resembling the type of cell seen lining gallbladder walls. This area somewhat resembles the intramural type of glandular proliferation seen in cholecystitis glandularis proliferans. Around the glandular areas, there is an especially noticeable concentration of chronic inflammatory cells."

Choledochus cyst was placed first on the list of possibilities preoperatively, because of (1) the finding of an ovoid mass; (2) its location in the right upper quadrant; (3) the pressure symptoms associated with it (distress after eating); (4) its cystic nature; (5) the presence of gas within it; (6) the altered gallbladder function, as shown by the Cole-Graham technic, and (7) the unlikelihood of the presence of some of the other possibilities. In treating this condition, surgery obviously is the method of choice. Good

anesthesia is of prime importance, and the continuous spinal method is a most satisfactory one. With the abdomen open, the first problem is one of identification and orientation. It takes some time before one can accomplish enough dissection, and that very carefully, to identify the pathologic lesion with which one is dealing (in this case the enveloping veil made injury to the duodenum and pancreas a likely possibility). This is the answer to those who would say

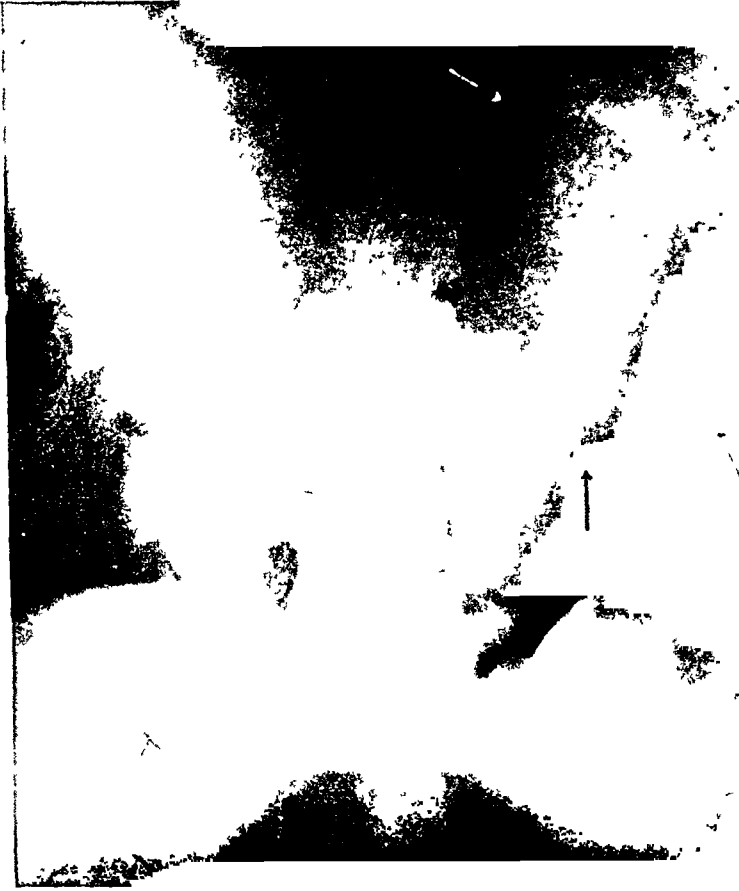


FIG. 17.—Roentgenogram taken in the case of a large solitary cyst of the lower pole of the left kidney. The cyst was comparable in size to the choledochus cyst. It shows the following contrasting points however: 1. The absence of gas. 2. The upward displacement of the kidney. 3. The distortion of the kidney pelvis.

that the treatment should be a simple anastomosis between the cyst wall and some segment of the gastro-intestinal tract. In the first place, the amount of dissection and separation necessary carries the operation beyond the simple stage. Secondly, to anastomose an unidentified cyst to intestine is bad surgery. Since the physical presence of the cyst itself gives rise to symptoms, its extirpation seems to be a logical step.

The duct leading from the cyst into the duodenum in this patient appeared to be a very real and patulous one, about the diameter of the lower end of a normal common duct. Apparently, the reason why this cyst did not give rise

to symptoms of biliary tract obstruction was that no constriction of the lumen of the duct *per se* existed. The onset of jaundice was imminent though, for the cyst contained such thick material that interference with complete emptying was only a matter of time. Most of the symptoms that were produced were the direct result of the pressure exerted by a mass of this size on adjacent organs, *i.e.*, on the stomach, pylorus and duodenum.

As to choice of operative procedure, this must largely depend on the findings in the individual case. The prime aims are to reestablish an unobstructed flow of bile into the gastro-intestinal tract and to remove or reduce in size the symptom-giving mass. In the present case, after dissection, the right and left hepatic ducts were isolated and were seen to join and form an apparently normal common hepatic duct, which entered the dome of the cyst; one and one-half centimeters to the right of this the cystic duct entered separately.

The decision was made to remove all the cyst except that small portion of the dome into which these ducts emptied and to anastomose this "dome" to the duodenum. This was mechanically simpler than using the common hepatic duct alone. Because the suture line was removed from the immediate termination of the hepatic duct, subsequent contracture of its ostium was less likely than if the duct itself had been directly concerned in the anastomosis. This method of approach also reduced the total operating time, already extended, by that which would have been consumed in removing the gallbladder. There seemed little hope that the bile would ever enter this gallbladder, yet, on the other hand, it was unlikely that duodenal contents would enter either, since the cystic duct presumably retained its valve-like structure intact. (Roentgenograms, taken later, showed no extension of barium into the biliary system—either into the cystic or hepatic ducts.) Then, too, this apparently inert and functionless gallbladder, if left in place, might prove useful in the construction of an alternate pathway for bile should an unexpected biliary obstruction develop postoperatively.

The operative anastomosis, as decided upon, went well, and the uncomplicated postoperative course seems to establish the steps herein taken as a different and acceptable means of dealing with a choledochus cyst.

#### SUMMARY

1. A case of that rare pathologic lesion choledochus cyst is reported. This case is unique in that the patient was a Negro, and that the diagnosis was placed first among preoperative choices. Anticipating the possible presence of this lesion is more important than making an exclusive diagnosis.
2. Roentgenologic examination was of extreme help in the evaluation:
  - a. By directing attention to the biliary tract in the finding of a "non-functioning gallbladder."
  - b. In outlining the cyst by means of views taken from various positions.
  - c. In demonstrating relation of the cyst to the gastro-intestinal tract.
  - d. By showing the presence of gas in the gallbladder above the cyst—a finding which, when present, would strongly hint at the diagnosis.

3. Operation consisted of removal of approximately nine-tenths of the cyst and anastomosis of the remaining portion of the dome (that part into which the cystic and common hepatic ducts entered) to the duodenum. The operation herein described is a practical and technically simple method of accomplishing anastomosis and, judging by the clinical results in this case, a very satisfactory one.

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# REPEATED MASSIVE INTESTINAL HEMORRHAGE

## REPORT OF AN UNUSUAL CASE

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MASSIVE BLEEDING from the upper gastro-intestinal tract is not uncommon with an ulcer of the stomach or the duodenum when the ulceration erodes into a large vessel, with tumors of the stomach, or with tumors of the small bowel. This case, however, is considered important because of the unusual etiology of the hemorrhage, the extent of the bleeding, and the amount of blood replacement therapy which was necessary in a short period of time. It is also considered worth while recording because of the possibility of similar cases occurring as the result of war injuries.

**Case Report.**—A member of an infantry unit on combat duty near Heilbronn, Germany, was struck in the left midaxillary line with shrapnel, on April 9, 1945, at about 1600, receiving a thoraco-abdominal wound. He received emergency treatment in the field consisting of compression dressing,  $\frac{1}{4}$  grain morphine, 4 Gm. sulfadiazine by mouth, and 2,000 units of penicillin. At 1900 on the same day he was admitted to a Field Hospital, where 500 cc. of plasma and 500 cc. of blood were administered. At 2100 he was operated upon under intratracheal ether and oxygen anesthesia. Preoperative blood pressure was 144/98; pulse 90.

The wound of entry was at the level of the seventh interspace. The chest was explored; the missile was thought to be lying below the left diaphragm, which had been lacerated. The wound of entry was débrided; and the sucking chest wound was closed. A formal thoracotomy was then performed through the left ninth interspace. The laceration of the diaphragm was seen to have a small amount of omentum herniating through it into the pleural cavity. The diaphragm was opened widely for exploration of the left upper quadrant. The missile found lying in the peritoneal cavity was removed. The spleen was lacerated. Splenectomy was performed, with double ligation of the pedicle. Four perforations of a segment of upper jejunum were found. These were closed with two rows of sutures. A through-and-through perforation of the transverse colon just proximal to the splenic flexure was exteriorized through a left subcostal stab wound, after closing the two perforations. The diaphragm was closed with interrupted sutures of heavy black silk. A thoracotomy tube was placed in the left costophrenic angle, and a small catheter in the second interspace anteriorly. Twenty-five thousand units of penicillin were placed in the pleural cavity. The chest wall was closed in layers.

Postoperative course was uneventful. On the second day 120 cc. of serous fluid and 240 cc. of air were evacuated from the left chest. He was evacuated by air from Germany to Paris on the 20th of April, where he was held for further evacuation to the Zone of Interior. Check-roentgenograms on the 23rd of April showed some haziness of the left lower lung fields, but "significant regression of the diffuse reaction noted on previous films" was observed. The remaining residuum was thought to represent a regressive pleural effusion. On 1 May, 1945, in Paris, moderate bleeding was noted from the colostomy wound. He was transported by air to the Zone of Interior, arriving at the Regional Hospital at Mitchell Field on 2 May, 1945.

At about 0530 on 3 May, bleeding from the colostomy was again noted. Plasma was started soon thereafter. Examination at 0830 showed marked pallor; no air hunger; blood pressure 80/55; and a pulse of 92, with all the evidence of impending severe shock. Chest

wounds were well healed. The colostomy in the left upper quadrant had exuded about one pint of dark red, clotted blood. The abdomen was not distended. There were no signs of fluid in the abdomen. A presumptive diagnosis was made of bleeding peptic ulcer. It was the opinion of the medical consultant that he should receive conservative ulcer treatment in the form of milk and cream, 60 drops a minute by tube. Whole blood transfusion was given slowly, 40 to 60 drops per minute, increasing the flow when the systolic blood pressure fell below 80 mm. mercury. At 1030 the same morning, the blood pressure was 98/40; the dressing was again saturated with clotted dark red blood. At this time he vomited explosively about 400 cc. of fluid, the last of which contained some unclotted blood. Blood pressure shortly afterward was 80/40. The possibility of thrombosis of the splenic vein was now also considered, with resulting esophageal and gastric varices. Later the same morning he vomited twice about three ounces of bright red blood. At 1215 the blood pressure had dropped below 80, and the pulse had risen to 108. A Levine tube was passed and the half milk and half cream mixture was run in slowly. A half hour later he vomited some food and dark colored blood. During the next hours, the blood pressure dropped ten more points, and the blood transfusion was stepped-up to 120 drops per minute. Shortly afterward he again vomited blood and food; the tube feeding was stopped. Oxygen by nasal catheter was begun. Blood pressure was 75/40, with a pulse of 124.

During the first 24 hours the patient received 14 pints of blood and one pint of plasma. He also received morphine in small amounts, 1 Gm. of calcium gluconate in distilled water, 500 mg. of vitamin C, 3.2 mg. of vitamin K, and 150 mg. of vitamin B-1. The blood was run in slowly, varying the speed of drop in an attempt to maintain his systolic pressure at approximately 80 mm. of mercury. A medical officer was in constant attendance to regulate the drop speed in accordance with blood pressure readings. By 0630 of the morning of 4 May, 1945 the blood pressure, in spite of close supervision, was 60/40, with a pulse of 156. The patient had had 26 copious stools from the colostomy, which consisted of little else than clotted blood. It was felt at the this time that the patient was slowly going downhill in spite of the administration of blood and fluids. The hemorrhage was continuing uninterrupted; it was believed that the bleeding must be from a large blood vessel. The problem then arose whether further conservative treatment was indicated, with the hope that the bleeding would abate, or whether an exploratory celiotomy should be performed. It was the opinion that any exploration would be hazardous, and the chances of finding the bleeding point if it should be in the area of the previously lacerated bowel not too good in view of the previous surgery. However, because the patient's condition seemed slowly becoming worse, in spite of extensive supportive measures for the past 26 hours, exploration was decided upon. The first choice of the site of the bleeding still continued to be the duodenum. Large amounts of blood in massive doses were to be given immediately preoperatively.

The patient was slowly transported by ambulance from the holding wards to the operating room. On arrival at the operating room, he seemed somewhat less pale, and claimed that he felt better. The blood pressure at that time was 100/62; pulse 120. In view of the slight improvement it seemed best to temporize to see if the bleeding would stop without exploration. During the remainder of the day he continued to improve; slowly receiving five additional pints of blood, bringing to 19 the total transfusions administered in 40 hours. In the evening his blood pressure was 125/70; and his pulse had dropped to 106.

The morning of 5 May he had a temperature of 105° F.; urine was negative. The medical consultant believed a pericardial friction rub was present and thought the findings might be on the basis of an azotemia. However, the N.P.N. was found to be 40. During the day he progressed satisfactorily. There was one bloody movement from the colostomy during the day, but no evidence of further bleeding. Urinary output was good during the 24-hour period. The blood values had been quite severely affected by the bleeding, as an analysis showed the specific gravity to be 1.044, plasma specific gravity 1.020, plasma protein 4.4 Gm. %, hematocrit 32%, hemoglobin 10.8 Gm. Two days later, on the 7th of May,

## MASSIVE INTESTINAL HEMORRHAGE

the R.B.C. was found to be 3,720,000, with a hemoglobin of 13.5 Gm., blood sp. gr. 1.053, plasma sp. gr. 1.024 hematocrit 40, plasma protein 5.85 Gm. %; the twenty-first pint of blood was administered. Following this transfusion he had a slight urticarious reaction. On the 8th of May at 1330, bloody stool was again noticed from the colostomy followed by several others in quick succession. These were quite copious and consisted almost entirely of dark black blood which was not clotted. Blood pressure dropped to 100/68; the pulse remaining at 72. The next morning, the 9th of May, the blood pressure was 100/68; pulse 66. His blood picture was approaching normal levels, with a specific gravity of 1.054, plasma sp. gr. of 1.026, plasma protein 6.5 Gm. %, hematocrit 40, hemoglobin 13.7 Gm. He had had only one bloody stool during the night. At 1445 on this day however he again began to bleed profusely through the colostomy. The pulse became weak, 110 per min., and the blood pressure dropped to 80/50. Blood was again started in both arms, running at 80 drops per minute; after one hour of this treatment the blood pressure was still 84/60. Several hours later he looked somewhat better although still having copious bloody stools. During this day he received four pints of blood, which totaled 25 pints administered since admission. Late that day his color was fairly good, he was hungry and seemed somewhat improved. It was believed that conservative therapy still was indicated in the hope that this might prove to be the last episode of bleeding.



FIG. 1.—Showing bleeding point in resected bowel.

On the morning of 10 May, however, bleeding again started in profuse amounts, with multiple stools of pure dark blood. Again, the patient became shocked, with continuing massive loss of blood from the colostomy. The bleeding continued well into the afternoon unabated. The patient definitely seemed to be slipping out of control, although blood was being run in rapidly in an attempt to maintain the blood pressure just above shock level, and not fast enough to increase the bleeding. Exploration of the colostomy with a finger did not reveal bleeding at or near the stoma. While blood was being run into three different veins in preparation for surgery, the patient had a severe shaking chill which lasted about 15 minutes. This was thought to be due to the temperature of the blood, which had been kept in the icebox and was therefore cold, when it was introduced into the multiple veins. Later in the afternoon, after 2,000 cc. of blood had been run in rapidly, he was taken to the operating room for exploration.

An upper right paramedian incision was infiltrated with 1% novocaine, and gas-oxygen supplementary anesthesia was used. On opening the peritoneal cavity there was no free blood or fluid found. Examination showed that both the large bowel and the small bowel contained blood, as indicated by its abnormal dark-bluish color. A high loop of jejunum was found adherent in the left gutter. This loop also contained blood. It was thought that this portion of the bowel was probably the site of the previous perforations. Because the duodenum was still considered the most likely site of the bleeding a longitudinal incision was made in it about two inches distal to the pylorus. When the duodenum was opened at this point, no free blood was found in the lumen, and there was no evidence of blood coming down from the stomach. A suction tip was introduced into the stomach; gastric



contents and gas were removed, but no free blood was found. A finger was then introduced distally in the duodenum downward and to the left across the midline. No free blood or clots were encountered. The duodenum was then closed in layers transversely. The previously described loop of jejunum which was adherent in the left upper quadrant was distended with several mushy clots; it was freed from the area of the previous operation. At a point about 12 inches distal to the ligament of Treitz the points of closure of four perforations were identified. Here, the jejunum was opened for a distance of two inches at its antimesenteric border. Many clots and also free bright blood were encountered. On removing these clots a mucosal defect was found in the site of one of the closed perforations (Fig. 1). This defect was about 2 mm. in diameter. A thrombus was protruding from it for a distance of 0.5 cm., and around the thrombus arterial blood was pumping into the lumen of the bowel. On removing the clot from the bleeding point extensive free arterial bleeding occurred. This area was about 1.5 cm. from the mesenteric border of the bowel. On examining the mesentery immediately beneath it, a good-sized artery could be identified. This vessel led directly up to the bleeding area in the closed perforation. The eroded area together with about one-half inch of surrounding bowel was excised. After excision of the piece of jejunum, a large artery could again be seen to have led directly into the site of erosion. This vessel was controlled by passing one cotton suture beneath it in the mesentery just before the vessel entered the bowel, which completely controlled the bleeding in the cut edge. Bowel continuity was then reestablished by an end-to-end anastomosis. Sulfanilamide was powdered into the area of the opened duodenum and the jejunal anastomosis. One thousand cubic centimeters of blood had been run in during the procedure. While in the operating room the blood pressure dropped to as low as 92/50, respirations 36; and pulse 180. The operating time was slightly less than two hours. By the end of the operation the blood pressure had risen to 110/60; and the pulse had slowed to 130.

The patient made steady improvement postoperatively. He was administered additional blood slowly over the next 24 hours, together with intravenous infusions of saline and distilled water containing vitamins and calcium. On the second day postoperative, he received his last transfusion, the thirty-fifth in the series. A blood count taken at this time showed the red cells to be 3,900,000, hemoglobin 90%. Final blood analysis two weeks after the operation showed blood specific gravity to be 1.059, plasma specific gravity 1.025, plasma protein 7.15 Gm. %, hematocrit 45, hemoglobin 15.3 Gm.

#### SUMMARY

(1) A case is reported of massive hemorrhage from the gastro-intestinal tract at the site of previous traumatic wounds of the bowel.

(2) Twenty-two days after injury, bleeding occurred in the area of one of the closed perforations and two days later it became massive.

(3) During the first 24 hours of this bleeding it was necessary to administer 14,500 cc. blood transfusions to replace lost blood.

(4) Recurrent bleeding in large amounts continued during the next seven days, which necessitated the administration of a total of 35 pints of blood, together with other fluids.

(5) Bleeding from such a previously sutured perforation is unusual, but should be kept in mind in patients with abdominal trauma.

# NEUROFIBROMA OF THE SMALL INTESTINE WITH MASSIVE HEMORRHAGE\*

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BENIGN TUMORS of the small intestine are comparatively rare. This is particularly true when one excludes growths arising from the ampulla of Vater and the ileocecal region. They may occur at any age, and are more frequent in males than in females, in proportion of two to one.

The most common benign tumors are lipomas, adenomas, hemangiomas, pancreatic rests, cysts and fibromas. The fibromas are the most rare of all tumors in the small intestine. Raiford<sup>7</sup> reported 21 cases, one of which was a fibroma; Rankin<sup>9</sup> reported 24 cases, six of which were fibromas; Morison<sup>6</sup> reported 21 cases of tumors of the small intestine, one of which was a pedunculated subserous fibroma; and Collins<sup>2</sup> recently reported a neurofibroma, and gave a description of the pathologic classification of these growths.

Herewith are reported two cases of neurofibroma of the small intestine that were pedunculated in type and caused very severe intestinal hemorrhage. Fibromas arise from connective tissue of the small intestine. They may be subserous, intermuscular, intra- or extraluminal, or they may be attached to the serosa and be pedunculated and not encroach into the lumen of the bowel. They may be pea-sized or they may be very large.

The fibroma is thought to arise from connective tissue elements of the small intestine, probably from the submucosa, or they may arise from connective tissue elements of the nerve or venous plexis, or from the muscular wall of the bowel. It is because of the various tissue elements comprising the tumors that the growths have been so variously named; hence, the tumor may be described as a fibroma, fibrosarcoma, fibroblastoma, leiomyoma, or many other names. The tumors are usually encapsulated. In most instances they are benign, although a low order of malignancy has been noted.

Fibromas of the small intestine may not produce any symptoms during life. The existence of the tumor may be found at autopsy. When symptoms are observed, vague intestinal discomfort is sometimes complained of. In most instances reported the symptoms of intussusception or volvulus of the intestine has led to the discovery of the growth at operation. Severe intestinal bleeding may also result because of the presence of these tumors but in most instances the tumor or tumors were found on abdominal exploration, since the presence of an intestinal tumor was not suspected. The production of a volvulus by these growths is easily seen because of their pedunculated shape and because the growth, as a rule, is at the antimesenteric border.

\* Modified from a paper presented before the Chicago Surgical Society, December 8, 1944.

The severe bleeding which the tumor causes is more difficult of explanation. In the two patients, whose histories are herewith reported, intestinal bleeding had been very serious and at operation the tumors were found to be of a pedunculated type with only a small portion of the tumor within the lumen of the intestine. The portion of the tumor within the intestine was only partially covered by mucosa, and there was no ulceration or erosion of the mucosa anywhere about the site of the growth. The tumors did not appear highly vascular and there were no large areas of degeneration to be seen.

The significant fact in the histories of both of these patients was that they had noted at times bright red blood in their stools.

#### CASE REPORTS

**Case No. 1.**—S. J., male, age 37, was admitted to the Presbyterian Hospital August 26, 1942. Black tarry stools had first appeared in October, 1941, lasting about three weeks, accompanied with weakness. Under treatment for anemia, he improved. Diarrhea with tarry stools occurring in attacks averaging about three days in duration occurred in February, April, June and August of 1942. There had been occasional burning epigastric distress without relation to the ingestion of food but he was relieved by the use of soda bicarbonate.

Physical examination was essentially negative. The erythrocyte count was 4,800,000, and the hemoglobin concentration 10.25 Gm. %. Fluoroscopic examination of the stomach disclosed spasm and deformity of the duodenal cap, without a definite crater.

Gastric analysis was within normal limits. Ulcer management was followed by improvement, but in February, 1943 the stools again became tarry, and in addition there was bright red blood. He was readmitted March 28, 1943 for exploratory celiotomy. Preoperatively, his condition was excellent; the hemoglobin concentration being 14 Gm. %; and the erythrocyte count 4,500,000.

**Operation.**—At celiotomy, the stomach and duodenum appeared normal, but the duodenum was opened because of the history of intestinal bleeding. This was closed after nothing unusual was observed. About 17 inches from the ileocecal valve a hard tumor was found on the antimesenteric border of the ileum, mushroom in shape, dusky red, and solid. It extended into the lumen for about one-quarter of an inch, and was covered with normal lining, although the surrounding mucosa was discolored as from old hemorrhage. The bowel was circumcised about the tumor, which was removed, and the opening sutured transversely, using three layers of catgut. The abdominal wound was closed without drainage. Recovery was uneventful; and no known recurrence of the bleeding has occurred to date.

**Pathologic Examination.**—*Gross:* The tumor after removal disclosed it to be in the shape of a mushroom, the larger portion of which was about 35 mm. in greatest diameter and corresponded to the extramural portion. The smaller portion, about 20 mm. in greatest diameter, represented the intramural and intraluminal portion, with a total thickness of about 30 mm. The dome of the smaller portion was covered with mucous membrane and that of the larger portion by a transparent serosa. The mucosa was intact except for a



FIG. 1.—Photograph of neurofibroma taken before removal.

minute dimple on the summit of the dome; into which a probe could be passed about 2 mm. On section, the neoplastic tissue was firm, pale tan-gray-white, fibrous in character, and with a slight tendency to interlacing. A few small hemorrhages were observed in the outer portion beneath the serosa but none near the mucosa. The possibility exists that the hemorrhages occurred as the result of manipulation during surgical removal (Figs. 1, 2 and 3).

*Microscopic Examination.*—Sections taken to include the entire tumor through one plane, stained with hematoxylin and eosin, *etc.*, disclosed the muscularis to be completely interrupted by the extension of the tumor through it, stretching of the mucosa and submucosa over the dome of the smaller portion, stretching of the serosa over the greater portion, and extension of a few of the muscle bundles of the muscularis superficially into the adjacent portions of the tumor. In addition, there were interlacing bundles of parallel cells, the cells having long slender nuclei with sparse cytoplasm separated by sparse stroma, the absence of mitotic figures, a sparse scattering of lymphocytes throughout and slight hyalinization in the subserosal portion. Vascularity was moderate, hemorrhages were sparse near the subserosal margin but were absent near the mucosa, corresponding to the gross observations, and necrosis was insignificant. A comparison of the neoplastic cells with those of the muscle cells of the muscularis disclosed the former to be larger and darker staining. *Pathologic Diagnosis.*—Neurofibroma, with a questionable origin from the muscularis of the small intestine.

**Case No. 2.**—A. M., female, married, age 33, was admitted to the Presbyterian Hospital, April 7, 1943, because of severe diarrhea, accompanied with tarry stools. Previously tarry stools with diarrhea, once with bright red blood, had been irregularly recurrent since the first attack in 1940, recurring in 1942 and in March and April of 1943. Following the last attack she fainted, and there was also nausea and vomiting, without blood in the emesis.

On admission, she was in mild shock, without abdominal pain or distress, and there had been no history of any abdominal or epigastric pain or distress, except for cramps with the diarrhea in 1942. The erythrocyte count was 2,600,000, and the concentration of hemoglobin 56 per cent. Blood pressure 90/60. A tentative diagnosis of peptic ulcer, with bleeding, was made and ulcer management was begun. In the first 24 hours after admission 1,500 cc. of whole blood were administered. The diarrhea with tarry stools and clots of blood continued. Thirty-six transfusions of blood, totaling 20 liters, were given during the first week. A short time following each transfusion, from 250 to 500 cc. of a dark, bloody stool was passed, with a subsequent drop in the blood pressure and a corresponding decreased erythrocyte count and hemoglobin value. Hykinone and calcium gluconate were also given. The bleeding suddenly stopped on the eighth day. The stools became free of occult blood within four days, and improvement was steady. She received another liter of blood; and upon discharge the erythrocyte count was 4,100,000, and the hemoglobin concentration 9.2 Gm. %. Proctoscopic and fluoroscopic examinations of the colon failed to substantiate the ideas of a polypus of the colon or a bleeding Meckel's diverticulum. The possibility of a duodenal ulcer was suggested by the fluoroscopic observation on only one occasion of a spasm deformity of the duodenum.

The patient was readmitted, February 3, 1944, because of the passage of tarry stools, and the performance of an exploratory celiotomy was decided upon. The hemoglobin concentration was 11.5 Gm. %; and her condition good.

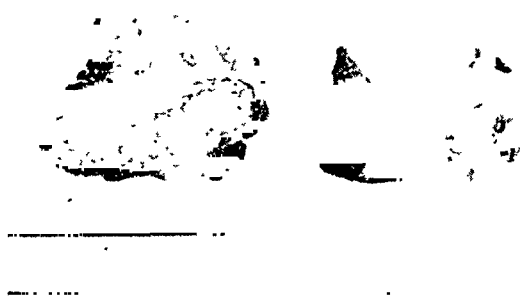


FIG. 2.—Neurofibroma of the ileum.

*Operation.*—A right upper paramedian incision was made, and examination of the stomach and duodenum was negative to external inspection and palpation. About five feet from the ileocecal valve a relatively large mushroom-like, firm, circumscribed tumor extending into the lumen for about one-quarter of an inch was observed on the antimesenteric border of the ileum. The lining over the tumor appeared intact but stained with blood, and a large mesenteric vein was attached to one side. The lymph nodes in the adjacent portion of mesentery were not enlarged. The intestine was circumcised around the tumor and the opening closed in the transverse axis with three layers of sutures. The abdomen was closed without drainage. Recovery was uneventful; and there has been no known recurrence of bleeding to date.



FIG. 3.—Neurofibroma of the ileum showing cut-section.

*Pathologic Examination.*—*Gross:* The specimen after removal disclosed it to be roughly mushroom in shape, up to 5 cm. in greatest diameter. It was covered with an intact mucous membrane, at the smaller end, while the larger portion had a serosal covering. On section, the bulk of the tissue was fibrous and a pale yellow-gray. Small cystic spaces resulted in a more spongy character of the zone beneath the mucosa, and this was bluish-red.

*Microscopic Examination.*—Two pieces, one to include the serosa and subjacent portion and the other the mucosa and subjacent portion, stained with hematoxylin and eosin, Foot preparations for reticulum and van Gieson preparations, disclosed the general character of the tumor to be one of interlacing bundles of parallel cells separated by a relatively sparse collagenous and reticular stroma. The neoplastic cells were abundant, with elongated fusiform nuclei rounded at their ends in longitudinal section, and polymorphic, small and dark on transverse section. Mitotic figures were not observed. In the subserosal portion there was a thin, fibrous capsule subjacent to which was a partial replacement of the neoplastic cells by a sparsely fibrinous edema fluid, leaving islands of cells arranged about blood vessels, the walls of which were thin and hyalinized. Lymphocytes were sparse. *Pathologic Diagnosis:* Neurofibroma of the wall of the small intestine.

*DISCUSSION.*—Clinically, each of the patients had relatively long-standing recurrent episodes of dark tarry stools which at times also contained bright red blood, in the presence of otherwise apparently good health. The abdominal distress in Case 2 was presumably associated with the diarrhea incident to the bleeding. In each case suspicion of duodenal ulcer existed and the ulcer management instituted was followed by recurrence of the bleeding. Conservative treatment in Case 2 during the episode of prolonged bleeding ultimately was followed by surgical intervention. Each patient recovered uneventfully without subsequent bleeding.

Anatomically, the lesions were alike in their fundamental character, shape, relation to the wall (antimesenteric, and both intra- and extraluminal), general location in the ileum (one, one and one-half feet and the other five feet from the ileocecal valve), and in their association with intestinal bleeding. They

differed chiefly in their size, and the larger had undergone slightly more advanced retrogressive change and hemorrhage within the tumor. In neither was the bleeding point identified although a minute defect on the summit of the mucosa of the smaller tumor (Case 1), perhaps associated with pressure atrophy, may have been of significance in the bleeding. Such hemorrhage as was observed was in the subserosal portion in each tumor away from the mucosa and may have been due to handling during removal. The more massive bleeding occurred with the larger tumor (Case 2). The changes of necrosis and inflammation were comparatively slight, and the inflammation observed was subacute exudative in type.

The significant fact in both of these patients was the history of recurring attacks of tarry stools and the observance by them of the occasional presence of bright red blood in the stool. The occurrence of the latter was suggestive of some lesion in the small intestine like a Meckel's diverticulum.

GENERAL DISCUSSION.—The prefix "neuro" used in the term neurofibroma implies a special origin, or character, to what is otherwise an essentially fibrous type of neoplasm. A study of the literature discloses some confusion in terminology of these tumors. The cell concerned is considered to be either from the sheath cell (Schwann cell) about a nerve fiber or the fibroblast of the delicate framework of connective tissue supporting the nerve fiber or fibers. The cells that compose these neurofibromas appear and act more like fibroblasts than otherwise, their presence being associated with the production of fibrils of reticulum and relatively sparse fibrils of collagen. These cells have also a resemblance to smooth muscle cells, not only individually but in their tendency to form interlacing bundles of parallel cells. Thus, there is a group of similar neoplasms of three different types, the fibroma (arising from the ordinary fibroblasts); the neurofibroma (arising from a special fibroblast-like cell associated with nerve fibers); and the leiomyoma or leiomyofibroma, (arising from smooth muscle cells alone or together with the ordinary fibroblasts). In the ordinary surgical pathologic examination there is no difficulty in distinguishing the fibroma from the other two, since in the fibroma there is usually no particular arrangement of cells in relation one to another and, except in the more cellular types, collagen is usually abundant. The neurofibroma and leiomyoma are not so easily separated, although definite criteria have been established for their microscopic diagnosis. Myofibrils, when demonstrated, allow a conclusive diagnosis of a leiomyoma. Their demonstration in the ordinary handling of surgical material appears to be difficult. Another feature, chiefly presumptive, is the relatively greater abundance of the cytoplasm, especially as compared to the nucleus both in longitudinal and cross-sections of the individual cells, in the leiomyoma. Interlacing of bundles of parallel cells is common both to the neurofibroma and leiomyoma. However, the two may be distinguished by a feature of the neurofibroma, which is believed to be fairly characteristic. This is a tendency to palisading of the nuclei, interpreted as due to division of the cells in their long axes. The degree of palisading in different tumors varies,

and there exist subclassifications based upon these variations. In the opinion of one of us, it is believed that all degrees of interlacing and of palisading may occur and that the variations do not represent a basic character justifying the division of the neurofibromas, in general, into groups of distinct entities. It is suggested that the differences in the patterns microscopically, for example, between a subcutaneous neurofibroma and an acoustic neurinoma, may depend upon the size and location of the nerve fibers concerned. Incidentally, it is not essential to the diagnosis to demonstrate an association of such a tumor with nerve fibers and the absence of such an association should not occasion doubt as to the diagnosis.

The demonstration of the point of origin of any particular tumor, as for example in the two cases reported, it is often impossible because of alterations resulting from the growth and size of the tumor when it makes itself clinically or otherwise apparent. Theoretically, they are believed to arise in association with nerve fibers wherever they may exist outside the central nervous system. In the small intestine these fibers occur throughout the wall, although they are most numerous in the two plexuses of the submucosa and muscular layers, respectively.

Grossly, a neurofibroma in the small intestine is an encapsulated tumor of variable size, slow in growth, and will produce symptoms depending upon the level at which it occurs, the degree to which it extends into the lumen and its susceptibility to hemorrhage.

*Surgical Significance.*—Eight correlations between the character of the neurofibroma of the intestine and their surgical significance are listed below:

1. They may be classed with the larger group of benign tumors, including adenoma, lipoma, etc.

2. Benign tumors are infrequent in the small intestine, so are not likely to be considered in a differential diagnosis. Malignant tumors of the small intestine, infrequent percentagewise, are numerically as frequent, or more so, than benign tumors.

3. Since benign tumors have been observed most frequently in the ileum and duodenum, this suggests that during an exploratory celiotomy these portions of the small intestine be examined first. In the two cases reported the tumors were found without difficulty.

4. At any one level of the intestine such tumors may occur at any point on the circumference, so as to be either antimesenteric, as in the cases reported, or to extend into the mesentery. If pedunculated, there exists predisposition to intussusception, with acute obstruction, in a patient previously well. The common cause of intussusception in an adult is a benign tumor. The existence of a pedicle will allow ready removal of the tumor, or natural processes may result in spontaneous amputation with the possibility of obstruction at some lower level.

5. The circumscribed and encapsulated character of a neurofibroma allows its ready and complete removal, a circumstance which may account for the absence of reported recurrence in the literature examined. This lack of recur-

rence is in contrast to that which may follow the removal of similar tumors in such locations as the retroperitoneal or subcutaneous tissues.

6. At exploration, the procedure of choice will be indicated by the circumscribed, somewhat mobile character of the lesion unassociated with adhesions in contrast to the changes associated with a malignant tumor. With the latter there is a common tendency to a napkin-ring type of constrictive obstruction, and extension of the neoplasm, although not necessarily present, may exist either directly into the adjacent structures with or without adhesions or to the adjacent mesenteric lymph nodes. The presence of adhesions is suggestive of either an inflammatory or a malignant neoplastic process.

7. The tendency to bleeding, which is reported as often pronounced with benign tumors of the duodenum, is presumably associated with several factors such as the vascularity of the mucosa, vascularity of the tumor, changes in the lining, such as pressure atrophy or ulceration, or ischemic necrosis of the tumor. In the two cases reported such changes were observed in a degree not corresponding to the volume of bleeding. Predisposition to hemorrhage occurs with the disseminated focal necrosis incident to scattered thrombi in the small vessels. Other factors may be involved and in this respect one may recall the common tendency to uterine bleeding with leiomyoma of the uterus where, of course, there is a recognized endocrine influence upon the endometrium.

8. Exclusive of other factors, the prognosis from the standpoint of the existence of a neoplasm is favorable. In the literature examined no recurrences have been noted.

#### SUMMARY

Two cases, each of persons with a neurofibroma of the small intestine, in which recurrent intestinal bleeding was the chief symptom and diagnostic problem are reported, with discussions of the cases, of the character, diagnosis and terminology of the entity neurofibroma and of eight considerations of surgical value. In patients with severe intestinal hemorrhage, especially when bright red blood appears in the stool and in whom the etiologic factor is doubtful, the possibility of the existence of a benign tumor of the small intestine should be considered and a search made for its presence.

#### LITERATURE

The following is a partial listing of reports concerning benign tumors of the small intestine, and is not intended to be exhaustive.

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<sup>5</sup> James, J. E., Jr., and Sappington, S. W.: Fibroma of the Small Intestine Resulting in Intussusception. *ANNALS OF SURGERY*, 65, 109-114, 1917.



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# ADENOLYMPHOMA OF THE PAROTID AND SUBMAXILLARY SALIVARY GLANDS

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TUMORS composed of a combination of epithelial and lymphoid tissue, arising in or near the parotid and, occasionally, the submaxillary salivary glands, have been reported with increasing frequency. The terminology of these tumors is confused by the fact that they have been reported under a number of different names, of which the following may be enumerated: Papillary cystadenoma lymphomatosum, cystadenoma lymphomatosum, adenolymphoma, papillary adenolymphoma, papillary cystadenoma in lymph glands, branchiogenic cystadenolymphoma, branchiogenic adenoma, cylindrocellular branchiogenic adenoma, onkocytoma and Warthin's tumor. This varied nomenclature is, in part, a reflection of the numerous attempts that have been made to account for their origin. From a review of the literature and a study of the cases presented below, it is evident that not all tumors having this same fundamental structure are identical in either histologic pattern or clinical behavior. Thus, a group of tumors exists and it is the purpose of this communication to attempt to clarify the nomenclature by presenting a working classification based on morphology and clinical behavior. Four new cases are presented, one of which is malignant.

## BENIGN ADENOLYMPHOMA

As suggested by Klemperer,<sup>1</sup> adenolymphoma has been retained as a general term to indicate any tumor of the salivary glands composed of a combination of epithelial and lymphoid tissue whether benign or malignant. The terms papillary cystadenoma lymphomatosum and cystadenoma lymphomatosum have been used to indicate papillary and nonpapillary variations of the same tumor. A closely related and possibly identical tumor has been designated adenoma lymphomatosum.

## CASE REPORTS

**Case 1.**—A white male, age 30, was admitted to the Framingham Union Hospital, October 29, 1944, complaining of a tumor of the right parotid region which had been present for approximately one year. For several months there seemed to be some variation in size, and the possibility of an intermittent obstruction of the parotid duct was at one time entertained.

Physical examination revealed no abnormalities except for a tumor 2.5 cm. in diameter, in the right parotid region near the angle of the mandible. It was well-encapsulated, fixed to the underlying tissues but not attached to the overlying skin. The regional lymph nodes were not enlarged.

At operation, the tumor was easily removed from its bed, which lay in the substance of the parotid gland. The postoperative course was uneventful, and there has been no recurrence to date.

Microscopic examination showed the structure to be identical with that of Case I. The papillary formations consisted of a core of lymphoid tissue, containing germinal centers, on which rested the same type of tall, columnar, pseudostratified epithelium. There was no evidence of ciliation.

**Case 3.**—A white female, age 70, was admitted to the Massachusetts Memorial Hospitals, May 10, 1945, complaining of a slowly enlarging mass in the left parotid region of two years' duration. Examination showed the mass to be well-encapsulated, nontender, and approximately 3 cm. in diameter. It lay anterior to the lobe of the ear, was not attached to the overlying skin but was somewhat fixed to the underlying parotid gland.

At operation, the tumor was found to be well-encapsulated and was shelled out of its bed without difficulty.

Microscopic examination (Fig. 4) showed large and small cystic spaces filled with dense, amorphous, eosinophilic material. The lining epithelium resembled that of the preceding cases, with no evidence of anaplasia or abnormal mitotic activity. The stroma consisted of a fine, fibrous reticulum densely infiltrated with mature lymphocytes. Many lymphoid follicles were noted. An outstanding characteristic was the complete absence of papillary processes projecting into the cystic spaces.

**Incidence.**—In 1898, Hildebrandt<sup>2</sup> first reported a similar tumor in a 41-year-old male. This case was mentioned in a series of 20 cases of cysts and fistulae of the neck, all considered to be branchiogenic in origin. It was not until 1910 that Albrecht and Arzt<sup>3</sup> described two cases which they believed to represent a specific tumor type. A review of the literature indicates that similar tumors have been reported with increasing frequency. In 1929, Warthin<sup>4</sup> reported two typical cases. He emphasized their rarity by stating that these were the only cases he had seen in a series of over 700 mixed tumors of the parotid, and over 500 branchial cysts. By 1932, Jaffé<sup>5</sup> was able to find reports of 21 cases. Harris<sup>6</sup> found 43 cases up to 1937. In 1942, Plaut<sup>7</sup> found 48 cases in the literature and reported 16 new cases of typical papillary cystadenoma lymphomatosum. He reported three additional cases which differed slightly from the usual histologic picture in that the epithelium consisted of low cylindrical cells with vesicular nuclei. Between the bases of these were small cuboidal cells, irregularly spaced. This epithelium lined small cystic spaces and was embedded in a stroma of lymphoid tissue containing germinal centers. A microscopically similar tumor has been reported by Fine.<sup>8</sup> Subsequent reports by Robinson and Harless,<sup>9</sup> Lederman,<sup>10</sup> Ackerman,<sup>11</sup> Ramage, *et al.*,<sup>12</sup> and Martin and Ehrlich,<sup>13</sup> together with the above cases, brings the total reported to date to 94.

Table I shows the age incidence by decades in the 92 cases in which the age is reported. Seventy cases, or 76 per cent, are in the fifth, sixth and seventh decades. Extremes of age are a child of 2.5 years, reported by Stöhr and Risak,<sup>14</sup> and a man of 92, reported by Carmichael, Davie and Stewart.<sup>15</sup> Of the 92 cases, 73 are reported in males, 17 in females and in 2 cases the sex is not stated. This is a ratio of 4.5 males to 1 female.

**Histogenesis.**—No completely satisfactory explanation for the occurrence of these tumors has been suggested. Of the several theories proposed, the following are the most important:

# ADENOLYMPHOMA OF SALIVARY GLANDS

The *branchiogenic theory* was first suggested by Hildebrandt, and has been favored by Ssobolew,<sup>16</sup> Ewing,<sup>17</sup> and others. These authors believed the tumors arose from the ectodermal portion of a branchial arch. The presence of large amounts of lymphoid tissue in branchial cysts, together with an embryonal type of epithelium, was the background of this hypothesis. The epithelial cells of the tumor have even been likened to the large, eosinophilic cells of the parathyroid gland.<sup>13</sup> Most modern authors agree that there is no convincing evidence for this hypothesis.

Kraissl and Stout,<sup>18</sup> after reviewing the work of Schulte, suggested that remnants of the "orbital inclusion," a vestigial structure which, in some carnivora, gives rise to the orbital salivary gland, might give rise to the tumor. This theory attempted to account for the lymphoid tissue as well as the epithelium. However, the orbital inclusion has not been demonstrated in man.

Hamperl,<sup>19</sup> after reviewing the work of Schaffer and Zimmerman, suggests that these tumors may arise from specific cells which he terms "*onkocytes*." These cells are said to develop from both secreting cells and the lining of ducts, by an increase in size and a peculiar differentiation of the cytoplasm, which assumes a finely granular appearance. The nuclei are located near the lumen, are frequently indented and are rich in chromatin. Inasmuch as they are never found before the age of 20, and only rarely before the age of 30, they have been considered a product of advancing years. After the age of 70 they are nearly always present in both sexes. Jaffé accepts this hypothesis and suggests the term "*onkocytoma*."

There are a number of objections to the onkocyte theory. Harris has pointed out that typical tumors have been reported in children, whereas Hamperl did not find onkocytes before the age of 20. Furthermore, these tumors have been found in relation to the parotid gland, rarely in relation to the submaxillary gland, and nowhere else. Onkocytes have been found in all three of the salivary glands, in mucus glands of the tongue, floor of the mouth, uvula, pharynx, esophagus, trachea and elsewhere.<sup>20</sup> Finally, onkocytes have been found with equal frequency in both sexes while tumors occur considerably more frequently in men.

Albrecht and Arzt first suggested that these tumors might arise from rests of *heterotopic salivary gland tissue* situated in lymph nodes lying within the substance of, or adjacent to, the parotid salivary gland. This theory had its origin in the work of Neisse<sup>21</sup> who showed that in the 120-mm. fetus, there are numerous lymph nodes lying within the substance of the parotid. These nodes have diffuse outlines and salivary tubules are scattered freely within their substance. When condensation and capsule formation later take place and these areas of lymphatic tissue develop into the preparotid nodes, it "usually happens

TABLE I  
AGE INCIDENCE

Age	Cases
1- 10.....	2
11- 20.....	3
21- 30.....	4
31- 40.....	6
41- 50.....	23
51- 60.....	25
61- 70.....	22
71- 80.....	6
81- 90.....	1
91-100.....	—
Total.....	92

that tubules are separated from the rest of the parotid."<sup>22, 23</sup> Neisse was able to demonstrate the presence of scattered acini, or whole lobules of salivary gland tissue in the periparotid nodes of newly born infants.

A careful study of six periparotid lymph nodes which we obtained from a new born infant dying of congenital heart disease, revealed similar structures. We are not certain that these are glandular in origin. It is possible that they are lymphatic sinuses lined by large, embryonal endothelial cells, which closely simulate low cuboidal epithelium. Further study of this point is desirable.

The chief objection to the glandular displacement theory, as pointed out by Martin and Ehrlich, is that conclusive evidence has not been presented to show that the lymphoid tissue in these tumors is actually part of a lymph node. An important consideration in this respect is the fact that lymph sinuses have not been described in any of the reported cases, nor were we able to demonstrate them in our cases.

Warthin concluded that the epithelium of the tumor was "precisely like that of part of the eustachian tube, which has a tall, stratified, ciliated, columnar epithelium, with many lymphoid follicles beneath the epithelium." He expressed the opinion that the tumor arises from a *heterotopia of mucus membrane from the pharyngeal entoderm*, representing either the upper respiratory tract or the eustachian tube. He described a polypoid tumor of the eustachian tube with an identical microscopic structure.

Warthin described the epithelium of his tumors as being ciliated. Wendel<sup>24</sup> also reported a case in which the epithelium was described as ciliated. All other authors have found nonciliated epithelium. A study of the illustrations in the presentations of these authors leads us to believe that true ciliation was not present, but, as in our cases, the free surface of the epithelium was covered with a thin layer of amorphous material which, in places, resembled cilia.

Harris has stressed the importance of ciliation, pointing out that while there is no convincing evidence that the tumors are of branchiogenic origin, the occurrence of ciliated cells would definitely indicate origin from a pharyngeal pouch. We should like to point out that lack of ciliation does not necessarily preclude the possibility of origin from a pharyngeal pouch or from heterotopic eustachian epithelium. It is well known that the degree of ciliation varies greatly in areas of normal ciliated epithelium. Thus, areas are encountered in which there is complete, or nearly complete, absence of cilia, immediately adjacent to areas that are heavily ciliated. Furthermore, ciliation is in some degree dependent on the functional necessity for cilia. For instance, in the fallopian tube, the degree of ciliation varies with the reproductive cycle. Obviously heterotopic epithelium giving rise to a tumor might be nonciliated regardless of its origin, and ciliation of tumor epithelium would be unlikely in any event, simply on the basis that the cilia could have no possible function.

We agree with Warthin that these tumors arise from epithelium and lymphoid tissue displaced from the pharyngeal entoderm or upper respiratory tract. The remarkable similarity between tumor epithelium and that lining the upper respiratory passages in the embryo is illustrated in Figures 5 and 6.

However, we do not agree with Warthin, and subsequent observers, that tumor and respiratory epithelium consists of two layers of cells, the outer cylindrical and the inner cuboidal. Careful study of many sections from the above cases, and of the published illustrations of other authors, leads us to believe that this appearance is due to pseudostratification. This being the basic pattern, deviations are to be expected in tumor growth. Among these deviations, concentrically arranged cell nests resembling the "pearls" of epidermoid tumors were frequently found in all of our cases. Similar changes, perhaps on a larger scale.



FIG. 5

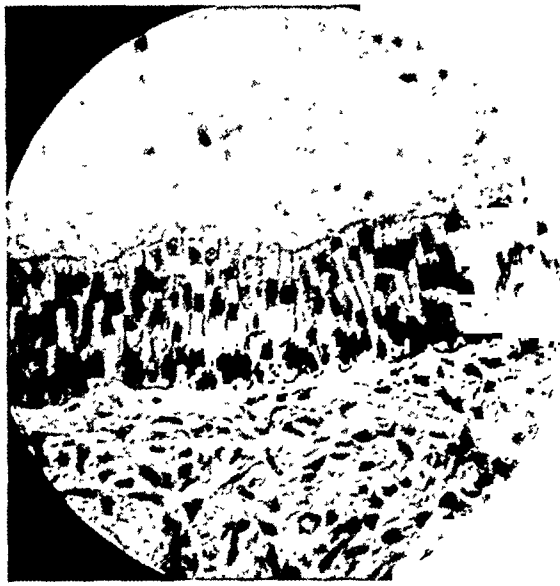


FIG. 6

FIG. 5.—Case 1: From a portion of papilla showing widespread pseudostratification of the nonciliated epithelial lining. Compare with Figure 6.

FIG. 6.—Mucosal lining of upper respiratory tract of embryo. Compare with Figure 5. (Slide loaned through the kindness of the Department of Anatomy of Harvard Medical School.)

were present in the second case reported by Ssobolew. In spite of the absence of mitotic figures and the lack of infiltrative power or metastatic involvement, he concluded, on the basis of these epithelial patterns, that a malignant change had occurred. A similar conclusion is certainly not justified in our cases.

*Clinical Course.*—These are slowly growing tumors, the duration before excision varying from a few months to over 30 years. Facial disfigurement is the common presenting complaint and the tumors are usually not painful or tender.

The mass is usually found near the angle of the mandible, or in the retro-mandibular area. Freshman and Kurland<sup>25</sup> reported such a tumor occurring at the anterior border of the superior portion of the sternomastoid muscle, and Wendel, Albrecht and Arzt and Spitznagel<sup>26</sup> reported tumors lying in relation to the submaxillary gland. Martin and Ehrlich believe the latter arose in relation to the tail of the parotid which, on its antero-inferior aspect, lies in relation to the submaxillary gland.

The tumors are about evenly divided between the right and left sides. Mar-

tin and Ehrlich report three cases with bilateral growths, in one of which multiple tumors occurred bilaterally. Ramage, Binnie and McCall also report a case with bilateral tumors, multiple on one side.

On clinical examination, the tumors are smooth in contour, thus, differing from the usual finding in mixed tumors of the parotid. They are moderately firm to fluctuant in consistency and, because of their invariable location near the surface of the gland, are movable to at least some degree.

Because of the obvious encapsulation and the presenting complaint, the diagnosis will usually not be made until the excised tumor is examined grossly and microscopically. Martin and Ehrlich found sialography of no great diagnostic aid. Aspiration biopsy was performed in 18 cases by the same authors. In only nine of these was a positive diagnosis made. In view of the difficulties encountered by the average pathologist in accurately interpreting slides made from aspirated material, there seems to be little place for this procedure.

*Treatment.*—The treatment of choice is surgical removal. Because the tumors are encapsulated and lie on or near the surface of the gland, this is usually accomplished without difficulty and with minimal danger to the branches of the facial nerve. Incomplete excision has been followed by recurrence in two tumors reported by Lederman and in one reported by Carmichael, Davie and Stewart. The latter recurred three years after excision and the recurrent tumor was not removed for an additional ten years. The histology of the original and recurrent tumors was the same except for some areas of "squamous metaplasia" (*vide supra*) in the recurrent tumor.<sup>6</sup>

The question of radiation therapy has been discussed by Martin and Ehrlich, who feel that the character of the lymphoid tissue, the presence of adenoid elements and cyst formation, do not augur well for its success. They point out that: "It has been fairly definitely established that hyperplastic lymphoid tissue is not highly radiosensitive and will not regress under irradiation unless the dosage is high." On the other hand, the two recurrences reported by Lederman were treated with radiation. One of these patients had remained free of disease for 15 months and the other for four years at the time of this report. A third case reported by Lederman had the tumor incompletely excised. Radium needles were inserted at the time of operation and the patient remained free of disease for three years, after which death occurred from other causes. Unfortunately the histopathology of Lederman's cases is incompletely reported. Certainly, the results of surgical excision have been so satisfactory that there is little place for radiation.

#### MALIGNANT ADENOLYMPHOMA

The question of the actual or potential malignancy of papillary cystadenoma lymphomatosum has been referred to by many authors, nearly all of whom regard them as benign. Martin and Ehrlich found no evidence of malignancy in any of their 22 cases. The case of Ssobolew has been discussed above. Lederman reported a case which died with definite metastasis following a combination of surgical and radiation treatment. The description of the micro-

scopic findings in this case is incomplete, but the epithelium was stated to be of the "basal" type.

Since these are the only cases of this type of tumor reported to be malignant, it is probable that true papillary (and nonpapillary) cystadenoma lymphomatosum is a benign tumor. That parotid tumors composed of adenoid and lymphoid tissues may occasionally be malignant, is illustrated by Case 4.

Case 4.—A white female age 48, was admitted to the Framingham Union Hospital, April 23, 1940, complaining of a slowly enlarging mass in the left parotid region of four months' duration. Physical examination revealed no abnormalities except a nodular, non-

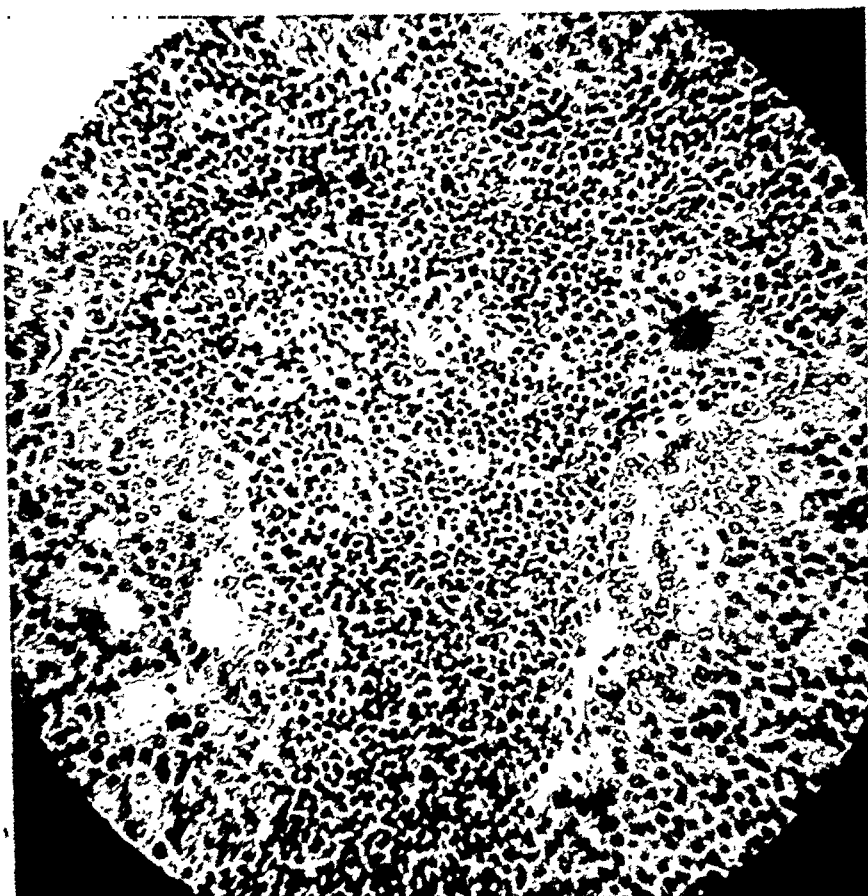


FIG. 7.—Case 4: Original tumor. Atypical glandular formations imbedded in a diffuse lymphoid stroma.

tender mass which lay in the substance of the parotid gland, posterior to the angle of the mandible. At operation, the tumor was found to be only partially encapsulated and to be deeply embedded in the substance of the parotid gland. With some difficulty it was excised, together with a considerable amount of surrounding, apparently normal, parotid tissue. The postoperative course was uneventful.

Examination of the specimen showed it to consist of a mass  $4 \times 2.5 \times 2.2$  cm. It was moderately firm in consistency, only partially encapsulated, with an uneven, nodular surface. On section, the peripheral portion was found to be normal parotid gland while the center consisted of tumor tissue which was firm, pale-gray, smooth and glistening.

Microscopic study showed no deviation from the normal in the sections from those portions which grossly resembled normal parotid gland. Beyond these areas there was widespread replacement of normal patterns by a new growth which consisted of atypical epithelial cells, irregularly mixed with lymphocytes (Fig. 7). The individual epithelial



cells were chiefly cuboidal, although displaying variations in size and shape. They had large round or oval nuclei with sharp limiting membranes and scanty chromatin networks. Some contained small nucleoli. The surrounding cytoplasm was homogeneous, compact and eosinophilic. In some areas these cells were disposed in acini from which new acini were being formed by budding. In other areas there were solid masses of cells.

Between the epithelial cells was a diffuse, dense infiltration of lymphocytic cells. These varied greatly both in size and cytologic characteristics. Some, rather large, with fine nuclear chromatin structure and two or more nucleoli, had the appearance of lymphoblasts. Others resembled mesolymphocytes, while others had the appearance of mature

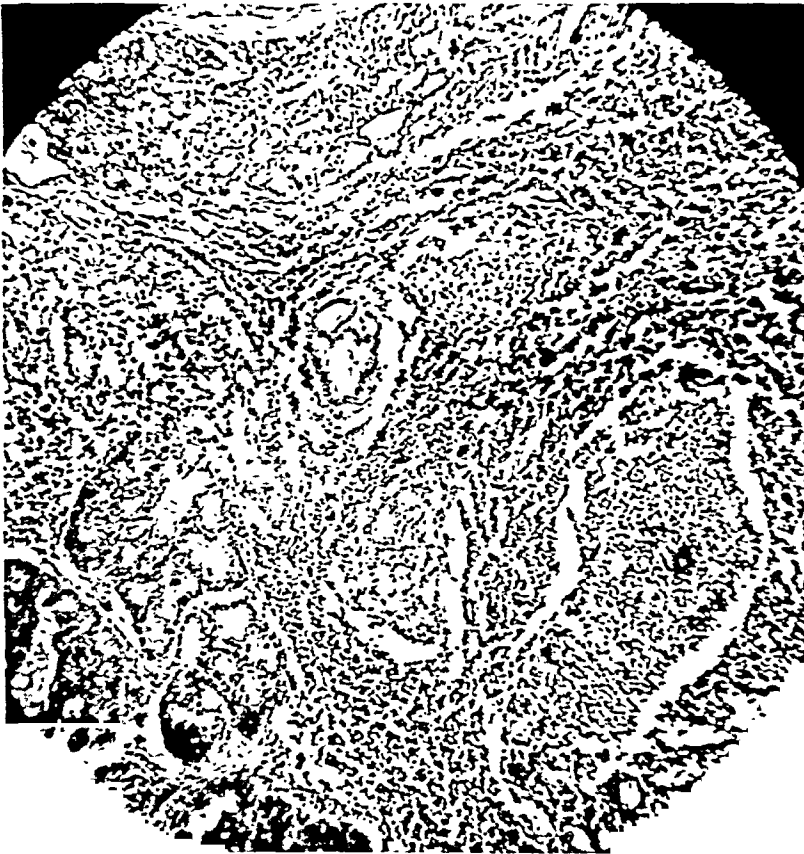


FIG. 8.—Case 4: First recurrence.

lymphocytes. All these different degrees of cellular differentiation indicated an active growth but lymph follicles were not seen.

Following operation the patient remained well for over three years, returning in August, 1943 with a recurrent tumor palpable in the retromandibular space underlying the old operative scar. At operation, the entire pharyngeal prolongation of the gland was found to be invaded by the tumor, which lay firmly wedged between the ramus of the mandible and the mastoid process. The facial nerve was isolated. Because it was inextricably involved in tumor tissue it was sacrificed and a wide resection of tumor and parotid gland was done. Convalescence was again uneventful.

Examination showed the specimen to measure 6 x 4 x 2.5 cm. Microscopic study (Fig. 8) showed the original characteristics to have been preserved. The lymphoid stroma showed all stages of cell maturation, from lymphoblasts to mature lymphocytes. The character of the epithelial proliferation did not differ greatly from that of the original tumor, except that the cells had assumed a more disorderly and infiltrative type of

growth. Individual cells showed great variation in size, shape and staining properties, and there were many atypical mitotic figures.

Following the second operation the patient remained well for one year, when she returned with a painless mass, 1.2 cm. in diameter, in the left submaxillary region. There was no evidence of recurrence in the region of the parotid or in the retromandibular region. No other enlarged nodes could be found in the neck or elsewhere. A suprahyoid neck dissection was done September 11, 1944.

Microscopic examination showed the histologic pattern to be similar to that of the preceding specimens (Fig. 9). The epithelial cells were anaplastic, with scanty, pale

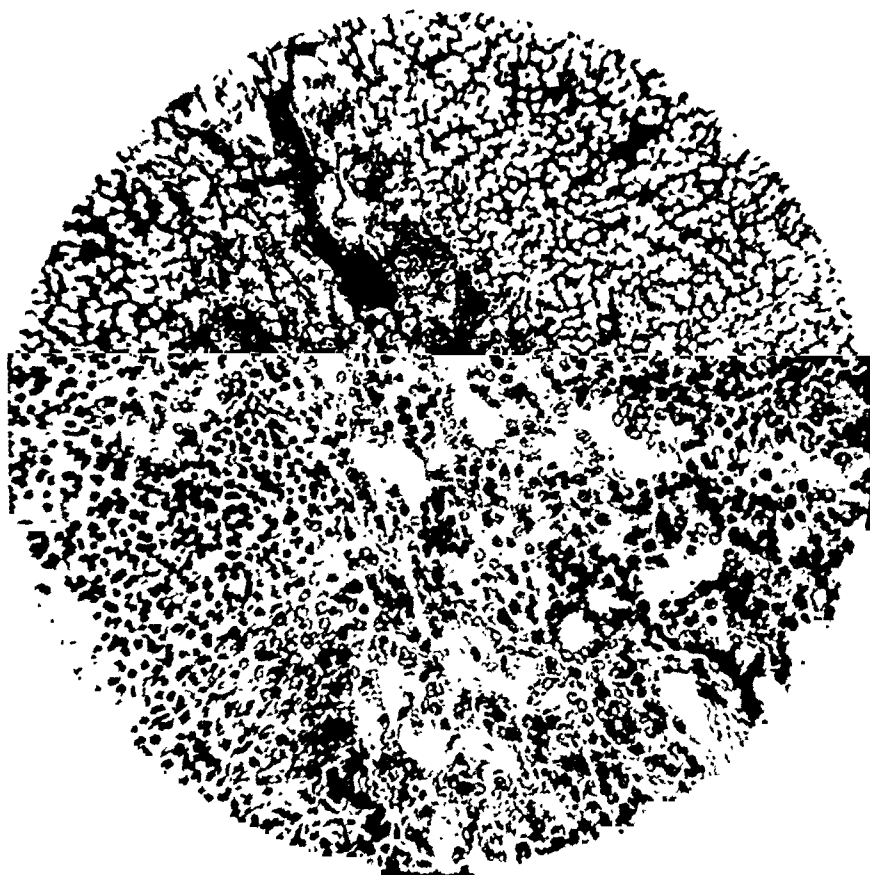


FIG. 9.—Case 4: Second recurrence, showing persistence of the mixed character of the growth.

cytoplasm, vesicular nuclei and many mitotic figures. Where the epithelial proliferation was most active and disorderly, the lymphoid stroma appeared greatly reduced, being entirely absent in places and limited to a few, irregularly scattered cells in others. Two small lymph nodes found in the removed tissue showed involvement with the same type of epithelial cells.

Following a review of the sections, a complete, radical dissection of the left side of the neck was advised. The patient refused to undergo further surgery. A course of roentgenotherapy consisting of 4200 r. was, therefore, given. A recent examination revealed no evidence of residual disease.

COMMENT: Case 4 presents unquestionable clinical and morphologic evidence of malignancy. Since its fundamental structure consists of an intimate mixture of glandular and lymphoid tissue, its relation to the benign tumors presents an interesting field for speculation. For instance, is this an example

of malignant degeneration of a benign adenolymphoma? While it is recognized that embryonal types of epithelium may dedifferentiate into malignant cells which have little resemblance to the parent cells, there is little in the morphology of the epithelium of this tumor to suggest such an hypothesis. The cell type and staining reactions are quite different. Furthermore, the relationship of epithelium to lymphoid stroma is entirely different. In Cases 1, 2 and 3 there is an harmonious relationship between the two elements, with no evidence of crowding or compression of one by the other. In Case 4 the lymphoid ele-



FIG. 10.—Parotid gland of human embryo 23 mm. long. Note similarity of glandular structures to those of the growth in Case 4, and the profusion of lymphocytes in the surrounding stroma. (Slide loaned through the kindness of the Department of Anatomy of Harvard Medical School.)

ment represents an active part of the growth, but its relationship to the glandular element is not harmonious. The pattern is that of two unrelated tissues growing simultaneously but without any orderly, predisposed arrangement. It is our opinion, therefore, that this tumor is not the result of malignant degeneration of one of the benign tumors.

Malignancy arising in the so-called "mixed tumors" of the parotid gland is not uncommon.<sup>27</sup> Foci of lymphocytes, or areas of diffuse lymphoid stroma, are occasionally found in these tumors.<sup>17</sup> While the origin of the mixed tumors remains a debatable point, it is possible that malignant tumors consisting of a

combination of epithelial and lymphoid elements, could arise from portions of a mixed tumor. Because a careful study of many sections from the original tumor in this case has failed to reveal any of the microscopic characteristics usually associated with the mixed tumors, such an origin seems unlikely.

Proliferation of cells of the lymphoid series at the site of tumor growth has been frequently mentioned and variously interpreted. A defensive rôle has been suggested but has not been generally accepted. In the embryologic development of the parotid gland there is a close association of lymphoid cells with glandular tissue (Fig. 10). Because the morphology of the epithelial cells of this tumor is similar to that of cells in the developing parotid gland, and because the original tumor was found deeply embedded in the substance of the gland, it is probable that it arose as a result of the dedifferentiation of the parotid epithelium. Because of the close embryologic association of epithelium with lymphoid tissue, the latter, also as a result of neoplastic stimulation, has taken on a concomitant but independent growth.

#### CLASSIFICATION OF ADENOLYMPHOMATOUS TUMORS

It is obvious that there are a number of different tumors occurring chiefly in the parotid region, but occasionally in the submaxillary region, all of which have in common a close association of epithelial and lymphoid tissues. Of these the benign papillary cystadenoma lymphomatosum is the most common, and this is a rare tumor. Harris has emphasized the occurrence of a purely cystic variation of this tumor similar to Case 3. In addition, Plaut, Fine, and others, have described benign tumors in which the adenomatous epithelium is low cuboidal, scanty and embedded in a lymphoid stroma containing germinal centers. Finally, malignant tumors, such as Case 4 and the first case reported by Lederman, occur in the same region.

Because of the plethora of terms used to designate the benign tumors, and the relative infrequency of malignant tumors, and, furthermore, because of a lack of definite information concerning their histogenesis, the following classification, based on morphology, is suggested as a basis for further study. Under this classification "adenolymphoma" may be used as a general term to designate any tumor of this region whose morphology consists of a more or less exclusive combination of epithelial and lymphoid elements, whether benign or malignant:

Adenolymphoma:

A. Benign:

1. Papillary cystadenoma lymphomatosum (Cases 1 and 2)
2. Cystadenoma lymphomatosum (Case 3)
3. Adenoma lymphomatosum (Plaut, Fine)

B. Malignant:

1. Adenocarcinoma lymphomatosum (Case 4)
2. Squamous carcinoma lymphomatosum (Lederman)

#### SUMMARY

1. Two cases of papillary cystadenoma lymphomatosum of the parotid salivary gland and one case of a purely cystic variety of the same tumor are

presented. These are rare tumors, occurring 4.5 times more frequently in men than in women.

2. The recorded theories of the histogenesis of these tumors are reviewed. We agree with Warthin that they probably arise from epithelium of the embryonic pharyngeal entoderm or upper respiratory tract, displaced to the region of the parotid gland.

3. Papillary cystadenoma lymphomatosum and its histologic variants are probably always benign. The results of surgical excision are excellent.

4. A morphologically and clinically malignant tumor of the parotid gland consisting of a combination of glandular and lymphoid tissue is presented. Its histogenesis is discussed.

5. A classification of adenolymphomatous tumors of the parotid and submaxillary regions is suggested.

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# PILONIDAL CYSTS AND SINUSES: A TECHNIC FOR EXCISION AND PRIMARY CLOSURE

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THE PURPOSE of this paper is to point out a method of surgical treatment which has resulted in an unusually high percentage of primary healing and an unusually low recurrence rate in the face of the rigors of military training and combat. From a military point of view pilonidal cysts should be excised only when there have been repeated recurrences of acute infection, or where chronic drainage is so profuse that the soldier cannot adequately care for himself under military conditions. Whether or not to excise an infected pilonidal cyst in civilian life depends upon the attitude of the patient and will not be discussed here.

While undertaking various types of surgical procedures for pilonidal disease it was demonstrated by bacterial cultures that a pilonidal wound is a sterile wound at the time of block excision. Contamination in closed wounds apparently occurred during the early postoperative period by way of the moist skin sutures. Sulfanilamide in the wound did not protect the tissue from infection, and made the wound wet and difficult to close. Sulfanilamide crystals placed externally proved to be hygroscopic enough to control the natural moisture of the area and bacteriostatic enough to control the invasion of the wound by infecting bacteria. It was also observed that wound reaction to cotton suture material was much less than to catgut, so a standard cotton technic was decided upon for this operation.

## SURGICAL REGIMEN

As a result of these observations, the following standard regimen was developed:

Pilonidal cysts showing acute inflammation are allowed to "cool-off" before operation. If drainage is inadequate, or if an abscess has formed, incision and drainage is performed, and the wound is packed open with vaselined gauze. Dakin's solution, hot sitz baths, and compresses are used to allay the acute infection. When cultures reveal staphylococci, penicillin is used. Subsequent curative surgery, if indicated, is undertaken only after the acute inflammation has subsided. This requires from two to three weeks. Early operation frequently results in a wet wound in which adequate hemostasis is difficult or impossible to obtain.

When the acute infection has adequately subsided, or if the infection is chronic, block excision of the cyst and sinuses followed by primary closure is done. The buttocks are strapped to the sides of the table to afford good expos-

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ure, and the area is thoroughly cleansed with soap and water followed by mercury bichloride solution. The area is carefully draped with moist towels and the bottom one is clipped into the skin just above the anus to protect the field from contamination (Fig. 1). The cyst is usually injected with methylene blue in peroxide solution if a patent sinus is present, and an elliptical incision is made. In cases where sinus openings are quite far lateral and where a "Y"-type of incision would seem advisable, the elliptical incision should still be used and carried laterally far enough to include the sinus openings. Actually, when very wide skin excisions are necessary, they can be closed without marked tension if the underlying subcutaneous tissue is properly built-up. We have several cases where large cysts with sinus ramifications necessitated elliptical incisions ten centimeters wide, and these were closed without difficulty.

The block excision must be wide enough to assure a thorough removal of the cyst, the sinuses, and all the tissue involved by chronic or subacute inflammation. The walls of the resulting wound should be vertical or sloping from the skin toward the midline when the adhesive traction straps are in place (Fig. 2). Undermining should be scrupulously avoided, or resorted to only in exceptional instances. Cutting into adjacent muscles and the creation of muscle flaps is not advisable and is never necessary.

All bleeding points are tied with No. 80 cotton. A minimal amount of tissue is included in each tie and the ties are cut "on the knots." The wound is irrigated with normal saline to remove any possible contamination, measured, and the adhesive traction straps are removed. The buttocks are pressed together so as to bring the walls of the excised area into apposition with each

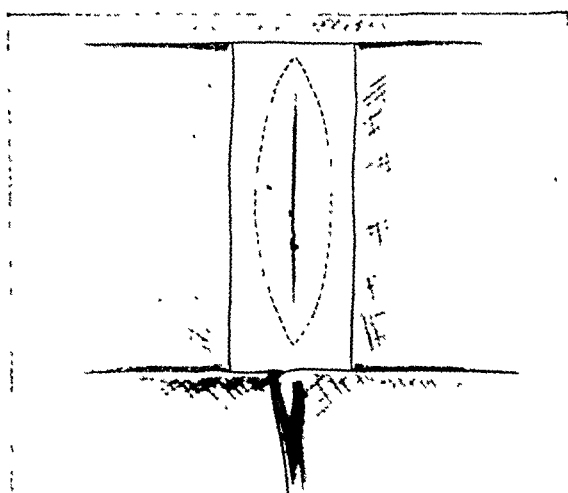


FIG. 1

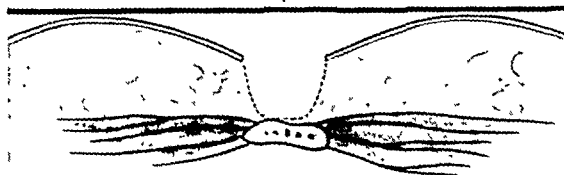


FIG. 2

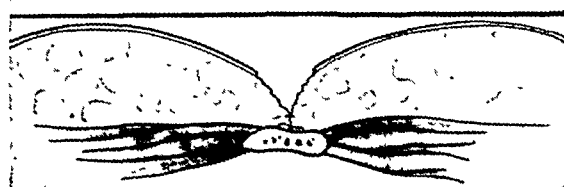


FIG. 3

FIG. 1.—The area is carefully draped with wet towels. The bottom towel is clipped to the skin to protect the field from contamination.

FIG. 2.—The block excision must assure a thorough removal of the cyst. Undermining should be avoided.

FIG. 3.—Care is taken to place the bottom row of sutures at a level where the deep tissue can be approximated without undue tension. The sacral fascia is never included in the deep suture layer.



other in order to determine the optimum levels at which to place the rows of subcutaneous sutures.

The wound is closed with No. 40 cotton sutures. The optimum level for the deepest layer of sutures is at that level where the fat can be approximated without undue tension. This level is usually a varying distance up the side of the wound rather than at the bottom of the wound, depending upon the width of the defect. The sacral fascia should not be included in the deepest row of sutures. These points in technic are emphasized. Sutures placed under much tension will pull through the fat during the early postoperative period, causing fat necrosis. The bottom row of sutures usually folds fatty tissue into the

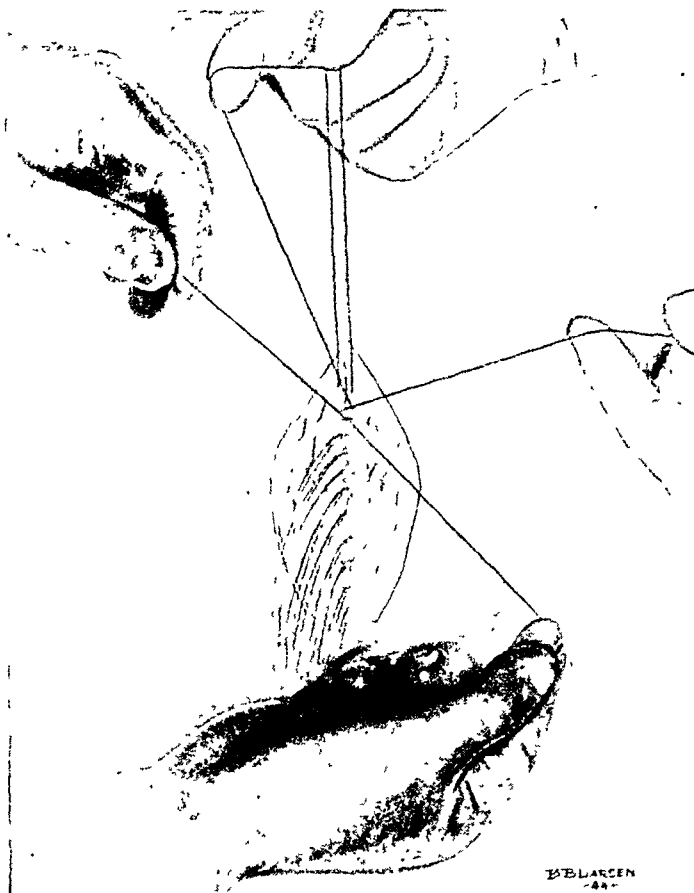


FIG. 4.—By properly holding the untied sutures, very little tension is applied to each suture in turn as it is tied. (Light gloves the assistant, dark gloves the operator)

bottom of the wound and no dead space remains. In some instances a dead space cannot be avoided; but this is of much less importance than obtaining good closure of the overlying fat without undue tension (Fig. 3).

The more superficial subcutaneous fat is built up with as many rows of sutures as are needed. Usually two rows are sufficient, but an additional half row is sometimes necessary at the lower end. (In one case, four and one-half rows of sutures were necessary to properly build up the subcutaneous fat.) The sutures are placed a row at a time, according to well-established silk tech-

nic, and then tied. Split-eye French needles facilitate this technic. By properly holding the untied sutures, very little tension is applied to each in turn as it is tied (Fig. 4). A strong suture line without bulky suture material is obtained. The tissue should be built up so that the skin edges are level and in close approximation. Care must be taken that the topmost row of sutures is not placed too close to the skin. There should be a space of from three to six millimeters between the knots of this suture layer and the deep portion or base of the skin (Fig. 5).

The skin is closed with meticulous accuracy by fine interrupted cotton sutures placed about five millimeters apart. These sutures are placed so as not to penetrate into the subcutaneous tissue as an additional safeguard against invasion of the fat by bacteria (Fig. 6). Sulfanilamide crystals are dusted on the closed incision, and a pressure dressing of mechanic's waste is strapped in place securely with adhesive tape.

Postoperatively, the dressing is not disturbed unless it becomes moist, bloody or contaminated, in which case it is changed immediately. When it is changed the sulfanilamide crystals are brushed off, or, if adherent, they are removed with boric acid or mercury bichloride solution. The dressing is then reapplied along with sulfanilamide crystals or zinc stearate powder. (Fifty

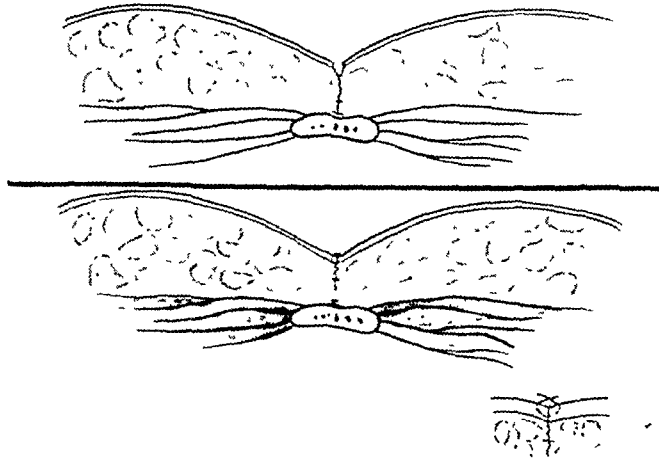


FIG. 5

FIG. 6

FIG. 5.—The tissue should be built up so that the skin edges are level and in close approximation. There should be a space of from 3 to 6 mm. between the knots of the top suture layer and the base of the skin.

FIG. 6.—The skin is closed with meticulous accuracy. The sutures are placed so as not to penetrate into the subcutaneous tissue.

controls showed no appreciable difference between the wound-healing in cases where sulfanilamide crystals were used throughout the postoperative course and in cases where zinc stearate powder was used after 72 hours following operation. This was not true if zinc stearate was used immediately following surgery. Sulfanilamide crystals tend to spill into the bed and cause discomfort. No discomfort is caused by zinc stearate.) After the initial pressure dressing has been removed the subsequent dressings are held firmly in place with gauze ties placed in adhesive straps. The incision is frequently inspected and zinc stearate powder or sulfanilamide crystals are reapplied as often as needed. If abnormal reaction occurs about a skin suture, that suture is immediately removed. Routinely, skin sutures are removed on the seventh to tenth postoperative day.

After the operation, these patients are given a liquid diet for three to four days, following which mineral oil is given to keep their stools soft. They are up and about in 14 days. In civilian practice, patients would be ready for discharge from the hospital at this time. In the Army the patient remains in the hospital, and after the third week is given reconditioning training to fit him for active duty six weeks following operation.

#### SUMMARY OF CASES

This report covers 225 consecutive cases of pilonidal disease operated upon and cared for by this surgical regimen. Two hundred and nineteen of the wounds were measured for length, width, and depth; one wound was measured for length and width; five wounds were not measured. Measurements were



FIG. 7.—Photograph taken 18 days after pilonidal cystectomy. Block excision measured 16 cm. long, 10 cm. wide, and 5.5 cm. deep. Primary healing, without complication.

made with the adhesive traction in place. The average size of the open wounds was 7.7 cm. long, 4.1 cm. wide and 3.7 cm. deep. The largest defect measured 16 cm. long, 10 cm. wide, and 5.5 cm. deep. This wound healed without complication (Fig. 7). In ten cases, other curative operations had been previously attempted. Three cases each had had three previous radical excisions, one case had two, and five cases had one attempted curative procedure. Low spinal anesthesia was used in all cases unless contraindicated. The operations were performed, after the procedure had been standardized, by the various Officers of the General Surgical Service and the Residents in Surgery at this Hospital. The average operating time for all cases was 36 minutes.

#### IMMEDIATE RESULTS

Primary healing occurred in 218, or 96.9 per cent, of these 225 cases, while infection with secondary healing occurred in seven cases, or 3.1 per cent, (Chart I).

The 218 cases which had primary healing have been divided into five subgroups:

(a) Those cases which healed by absolute primary intention, showing no clinical abnormality of any kind in the wound during the healing period. There were 191 of these, or 84.9 per cent of the total 225 cases.

(b) Those cases in which the skin edges were not approximated with

# PILONIDAL CYSTS AND SINUSES

complete accuracy, resulting in one skin edge overlapping the other, causing a small area of separation of the epithelium. There were 11 of these cases, or 4.9 per cent of the total.

(c) Pressure necrosis of the skin due to the technical error of tying the skin sutures too tightly. This occurred in two cases, or 0.9 per cent of the total. The necrosis did not exceed five skin sutures in either case.

(d) Cutaneous "stitch abscess" occurred in seven cases, or 3.1 per cent of the total. A cutaneous "stitch abscess" is defined as a purulent reaction about a skin suture which quickly subsides on the removal of the involved suture.








PRIMARY HEALING			
218 CASES — 96.9%			
ANALYSIS			
	ABSOLUTELY PER PRIMUM	191 CASES	84.9 %
	SLIGHT OVERLAP OF SKIN	11 CASES	4.9 %
	PRESSURE NECROSIS OF SKIN EDGE (NOT OVER 5 SUTURES)	2 CASES	.9 %
	CUTANEOUS STITCH ABSCESS	7 CASES	3.1 %
	SUBCUTANEOUS STITCH ABSCESS	7 CASES	3.1 %
		TOTAL	96.9 %
INFECTED — HEALED BY SECONDARY INTENTION			
7 CASES — 3.1 %			
ANALYSIS			
	MODERATE (NOT OVER 1/4 OF WOUND)	3 CASES	1.3 %
	MODERATELY SEVERE (NOT OVER 1/2 OF WOUND)	4 CASES	1.8 %
	SEVERE (OVER 1/2 OF WOUND)	NONE	0.0 %
		TOTAL	3.1 %

CHART I.—Analysis of immediate results.

(e) Subcutaneous "stitch abscess" consisting of infection about one or two, but not exceeding two, subcutaneous cotton sutures. There were seven of these cases, or 3.1 per cent of the total. A subcutaneous "stitch abscess" is defined as the purulent reaction about a subcutaneous suture which quickly subsides on the removal of the involved suture.

The seven cases which had secondary healing due to infection have been divided into three subgroups:

(a) Moderate infection, which involved not over one-fourth of the pilonidal wound. There were three cases of moderate infection, or 1.3 per cent of the total.

TABLE I  
SUMMARY OF CASES OF SECONDARY HEALING FOLLOWING INFECTION\* IN THE IMMEDIATE POSTOPERATIVE PERIOD

No.	Infection	Height	Weight	Recent Inflammation (Acute)	Size of Excision Length, Width, Depth (Cm.)	Special Operative Notes	Time of Operation (Minutes)	Remarks
1.	Moderate	6'1 $\frac{3}{4}$ "	218	I & D 200 cc. pus 18 days before operation	12 x 6.5 x 4	Approximately 4 times normal amount of bleeding. Required great deal of suture material	87	Third postoperative day quite marked induration lower end of incision. Seventh day wound open lower end with moderate purulent drainage. No recurrence 185 days postoperative
2.	Moderate	5'10 $\frac{3}{4}$ "	185	None	10 x 5 x 3.5		45	Fifth postoperative day evidence of superficial infection, one-half of skin sutures removed. Completely healed by 23rd postoperative day. No recurrence 158 days postoperative
3.	Moderate	5'11"	230	I & D abscess 2nd hospital day; I & D 30th hospital day; operation 33 days after last I & D	Not recored	Very wet wound. Operator questioned if attempt at closure justified	67	Second postoperative day 10 cc. hematoma evacuated and area became secondarily infected. Completely healed 28th postoperative day. Recurrent drainage on 38th postoperative day. Wound reopened and granulation tissue excised on 56th postoperative day. Slight recurrent drainage three months later which healed rapidly. No evidence of recurrence 219 days postoperative
4.	Moderately severe	5'10 $\frac{1}{2}$ "	157	Moderately inflamed. Compressed for 4 days preoperative	6 x 2.5 x 2.5	Very wet wound. Oozing could not be adequately controlled. Hot packs, etc., at least 3 times usual number of times	57	First postoperative day dressing saturated with blood. Evacuation of infected hematoma from superficial portion of wound 6th postoperative day. This portion healed by secondary intention. No evidence of recurrence 110 days postoperative
5.	Moderately severe	5'10"	200	Increased drainage and soreness for three weeks before operation	5 x 3 x 3		18	Initial healing normal except for moderate induration upper end of wound. 18th postoperative day fluctuant area at the upper end, 5 cc. of pus. Healed rapidly. Recurrent fluctuant abscess 60th postoperative day, incised and drained, several subcutaneous cotton sutures removed. Apparently healed 12 days later. Drainage recurred one month later. Healed slowly by secondary intention. No recurrence 220 days postoperative
6.	Moderately severe	6'2"	180	None	10 x 2		40	There was marked overlapping of skin resulting in superficial infection lower one-half of wound which healed by secondary intention. Recurrent drainage 61 days postoperative and two subcutaneous infected cotton sutures were removed. No recurrence 236 days postoperative
7.	Moderately severe	5'11"	225	Chronic profuse drainage	8 x 4 x 3.5	Unusually wet wound	50	Bleeding on defecation at stool 6th postoperative day which recurred 2 days later and infection in the wound became evident. Wound opened 3 cm. in length and 1.5 cm. in depth, packed. Healed by secondary intention. No recurrence 219 days postoperative

\* Moderate infection—not over one-fourth of wound involved.  
Moderately severe infection—not over one-half of wound involved.  
Severe infection—more than one-half of wound involved. (No cases.)

(b) Moderately severe infection, in which not over one-half of the wound was involved. There were four cases of moderately severe infection, or 1.8 per cent of the total.

(c) Severe infection, in which over one-half of the wound became infected. There were no cases of severe infection.

The seven cases which became infected in the immediate postoperative period are summarized in Table I. Analysis reveals that five of the seven had either recent acute inflammation or profuse chronic drainage. In four of the five, the operative wounds were so wet that special remarks to that effect were incorporated in the operative notes. In three of these postoperative bleeding in the wound was evidence of inadequate hemostasis. Cases 1, 3, 4, 5 and 7 emphasize the necessity for patience in allowing inflammation to subside. If possible, all clinical evidence of inflammation should be cleared up before curative surgery is attempted. In Case 6, infection occurred because there was overlapping of the skin, which was a technical error. There is no obvious explanation for the infection in Case 2.

#### LATE RESULTS

Of these 225 cases of pilonidal cystectomy, 220 were followed after leaving the hospital for an average of 124 days after operation. It was necessary to gather some of the information by letter from soldiers serving in various Theaters of War. After returning to military duty, five patients (2.2 per cent) could not be followed; 197 (87.6 per cent) had no recurrent drainage or other evidence of infection at the site of operation; 23 (10.2 per cent) had recurrent drainage.

The 23 cases which had recurrent drainage are summarized in Table II. Analysis reveals that no case of drainage represented a true recurrence of the pilonidal cyst. In no case was reëxcision indicated. In most instances, drainage was due to infection about one or two subcutaneous cotton sutures, and the lesion healed when the offending suture material was removed. It is significant that these sutures are usually at the lower end of the wound where it is difficult to keep the sulfanilamide crystals on the incision, and where the danger of contamination is greatest. It is also significant that there is no instance of drainage from the deep portion of a wound where a "dead space" is most likely to occur at the time of operation.

#### SUMMARY

A successful surgical technic for primary closure following complete excision of pilonidal cysts is presented. From a military point of view, radical surgery should be reserved for patients with frequently recurring acute infections or profuse chronic drainage. Curative operation is delayed until the lesion is quiescent. The lesion is completely removed by elliptical block excision. Undercutting, muscle flaps, and extensive dissections with plastic closures are not necessary or desirable. The wound is closed with cotton sutures employing meticulous "silk technic." Care is taken to place the deepest row of

TABLE II  
SUMMARY OF CASES WHICH HAD HEALED BUT DEVELOPED DRAINAGE DURING FOLLOW-UP PERIOD

No.	Postoperative Difficulty	Height	Weight	Recent Inflammation (Acute)	Size of Excision Length, Width, Depth (Cm.)	Special Operative Notes	Time of Operation (Minutes)	Remarks
1.	None	5'7"	168	Recent acute inflammation draining pus	Not recorded	Lower end of incision is 1 cm. from anal orifice	28	Drainage from extreme lower end of excision on 39th postoperative day. Single cotton subcutaneous stitch. No recurrence 187 days postoperative
2.	None			Indurated, up and to left at point of recent drainage	7 x 4		26	Drainage on 40th postoperative day. One subcutaneous cotton stitch. No recurrence 106 days postoperative
3.	None	6'1"	205	Palpable indurated mass 11 o'clock from sinus	12 x 6 x 3.3	Very extensive cyst. Opened into during operation	47	50th postoperative day slight bleeding. One subcutaneous cotton suture. Healed in 8 days. No recurrence 149 days postoperative
4.	None	5'7"	173	I & D 8 days before operation	3.5 x 1.5	Wet wound	50	46th postoperative day pain. 48th postoperative day drainage. Wound opened 1.5 by 1 by 0.3 cm. No suture found. Healed in 10 days. No recurrence 103 days postoperative
5.	None	5'6"	250		12 x 7 x 3	Extremely fat	33	115th postoperative day slight drainage. One subcutaneous cotton suture
6.	None	6'	155	None	3 x 1.75 x 1.5		55	49th postoperative day slight drainage. One stitch removed. Healed Drainage recurred 55 days later. Three subcutaneous cotton sutures removed. No recurrence 162 days postoperative
7.	None	5'9"	170	None	8.5 x 3.5 x 3		25	48th postoperative day drainage from extreme lower end of incision. Two subcutaneous sutures. No recurrence 138 days postoperative
8.	None	5'8"	175	Purulent drainage	10.5 x 6.8 x 5		39	46th postoperative day slipped on ice, fell on buttocks, split. open scar superficially 1 cm. long
9.	None	5'6"	155	One sinus opening	6 x 3.5 x 3		30	43rd postoperative day small subcutaneous abscess drained
10.	None	6'	185	None	8.8 x 4 x 2.5		17	45th postoperative day epithelium denuded from small portion of scar due to irritation of dense hair doing "sit-ups." One month later recurrence of same difficulty. One month later slight drainage. One subcutaneous cotton suture
11.	None	5'8½"	155	None	7 x 4 x 2		40	54th postoperative day drainage. Single cotton suture. No recurrence 90 days postoperative
12.	None	5'7"	170	None	8 x 4 x 4		40	(Letter) One month after operation after trip across country in a day coach, there was drainage followed by healing, and no recurrence 135 days postoperative
13.	None	5'5½"	168	None	5.7 x 4.2 x 3.1		38	(Letter) 108th postoperative day drainage. Wound opened 2 x 1 x 1 cm., curetted in another hospital. Healed rapidly
14.	None	5'10¼"	255	Mildly infected	13 x 8 x 6	Several widespread sinus openings. Wide, large incision. Very fat	45	135th postoperative day bloody drainage. Three pin point openings. Wound opened 2.5 cm. long, 6 mm. deep. Hair.* An immediate closure with wire. Primary healing. No recurrence
15.	None	5'5"	150	None	6 x 2.5 x 3		23	187 days postoperative (49 days after second operation) long, 0.3 cm. wide, denuded by irritation of dense, coarse hair. No purulent drainage. No recurrence 112 days postoperative

TABLE II—Continued  
SUMMARY OF CASES WHICH HAD HEALED BUT DEVELOPED DRAINAGE DURING FOLLOW-UP PERIOD

No.	Postoperative Difficulty	Height	Weight	Recent Inflammation (Acute)	Size of Excision		Special Operative Notes	Time of Operation (Minutes)	Remarks
					Length, Width, Depth (Cm.)	Depth (Cm.)			
16.	None	5'8"	117	Small amount of purulent drainage	7.5 x 5 x 4	7.5 x 5 x 4	Incision extends down into rectal sphincter	75	41st day postoperative noticed pain. Eight days later draining. Small opening extreme lower end. Subcutaneous cotton suture. No recurrence 192 days postoperative, but letter written on 286th postoperative day says he had recurrent drainage. Surgeon reports discharge due to traumatic abrasion of scar. No evidence of recurrence of cyst
17.	None	5'10"	150	Tender	No record	No record	One opening 3 cm. left of midline	40	15th postoperative day drainage extreme lower end of wound. One subcutaneous cotton suture. No recurrence 285 days postoperative
18.	Skin separation	5'8"	165	None	9 x 5.5 x 3	9 x 5.5 x 3		35	Recurrent drainage 45th postoperative day. Subcutaneous cavity 2.5 cm. long opened; secondary healing. No recurrence 126 days postoperative
19.	Skin separation	5'7½"	170	None	11.5 x 7 x 4	11.5 x 7 x 4		10	107th postoperative day drainage lower end, opened 2.5 cm. 1 cm. Healing progress slow. 198 postoperative day secondary closure 1.5 cm. with wire. Primary healing. No recurrence 128. days postoperative
20.	Subcutaneous "stitch abscess"	5'8"	185	Chronic continuous drainage	5 x 3 x 2.5	5 x 3 x 2.5		30	One subcutaneous cotton suture. Recurrent drainage from same area 83 days postoperative. No evidence of further recurrence 150 days postoperative
21.	Moderate infection	5'11"	230	I & D abscess 2nd hospital day; I & D 30th hospital day; operation 33 days after last I & D	Not recorded	Not recorded	Very wet wound. Operator questioned if attempt at closure justified	67	Second postoperative day 10 cc. hematoma evacuated and area became secondarily infected. Completely healed 28th postoperative day. Recurrent drainage on 38th postoperative day and wound reopened and granulation tissue excised on 56th postoperative day. Slight recurrent drainage three months later which healed rapidly. No evidence of recurrence 219 days postoperative
22.	Moderately severe infection	5'10"	200	Increased drainage and soreness for three weeks before operation	5 x 3 x 3	5 x 3 x 3		18	Initial healing normal except for moderate induration upper end of wound. 18th postoperative day fluctuant area at the upper end should be determined. 5 cc. of pus. Wound healed rapidly. Recurrent fluctuant abscess 60th postoperative day incised and drained, several subcutaneous cotton sutures removed. Apparently healed 12 days later, but drainage recurred one month later. Healed slowly by secondary intention. No recurrence 220 days postoperative
23.	Moderately severe infection	6'2"	180	None	10 x 2	10 x 2		40	There was marked overlapping of skin resulting in superficial infection lower one-half of wound which healed by secondary intention. Recurrent drainage 61 days postoperative and two subcutaneous infected cotton sutures were removed. No recurrence 236 days postoperative

\* This lesion was located in the midportion of the old scar and was very superficial. Therefore, it would seem this is not a true recurrence of the pilonidal cyst but a collection of hair, growing from hair follicles partly amputated at the original operation, which did not find its way through to the surface.



sutures at a level where the deep tissue can be approximated without undue tension. The sacral fascia is never included in the deep suture layer. Sulfanilamide crystals are dusted on the closed incision, where they control moisture and bacterial growth sufficiently to protect the wound from infection, and a pressure dressing is applied.

This report covers 225 consecutive cases of pilonidal disease operated upon and cared for by this surgical regimen. Primary healing occurred in 218 cases (96.9 per cent), and secondary healing occurred in seven (3.1 per cent). During the follow-up period, which averaged 124 days, 197 cases (87.6 per cent) had no recurrent drainage, 23 (10.2 per cent) had recurrent drainage, and five (2.2 per cent) could not be followed. No case with recurrent drainage represented a true recurrence of the cyst, and in no case was reëxcision indicated.

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# BASIC PRINCIPLES IN GERIATRIC SURGERY\*

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"Cast me not off in the time of old age;  
When my strength faileth, forsake me not."

Psalm 71:9

IN JULY, 1939, a new and well equipped 1,500 bed municipal hospital was opened in New York City for the treatment of chronic disease. It was the product of the foresight and the meticulous planning of the Commissioner of Hospitals, the late Dr. S. S. Goldwater. He had realized for many years that there were insufficient accommodations for patients with chronic diseases, that for the most part therapy in such disease was inadequate because of forced curtailment of hospital days, and that there existed a crying need for research in the causes, prophylaxis and treatment of chronic illnesses. The hospital was so organized that at least a beginning in the solution of some of these problems might be made. A sufficient number of surgical beds was provided, with no time limit on hospitalization. This afforded an unusual opportunity for continuous and unhurried study, therapy and the observation of end-results.

The primary purposes of the hospital were such that logically most of the surgical beds have been occupied by patients in the old-age group. In many instances they had been shuttled from hospital to hospital or they had remained at home without proper attention or therapy. They had become custodial cases, the victims of therapeutic defeatism and inadequate facilities for their care. It was realized that there would be many difficult problems, but the challenge was met by the conscientious application and coöperation of the hospital personnel and by the guidance and executive ability of the Surgical Director of our Division, Dr. Condict W. Cutler, Jr. .

It is the aim of this paper to present briefly some of the more basic principles in geriatric† surgery. Many of these are well known, but they bear repetition. A detailed description of pathologic conditions and technics will not be attempted.

## OLD AGE DEFINED

Gerontology relates to the study of the aging process. It is difficult to establish a line at which old age begins. The expressions "a man is as old as he feels" and "a man is as old as his arteries" are well known. Generally speaking, when the degenerative processes, whether due to inflammation,

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\* Read before the New York Surgical Society, October 24, 1945.

† The word "geriatrics," coined by Nascher,<sup>1</sup> is derived from the Greek: *γηρας*, old age, and *ιατρικός*, relating to a physician.

metabolic or neoplastic changes, affect individuals past the age of 60, it is customary to place such people in the old age-group. And yet many people past 70, who feel and function perfectly well, are nevertheless called "old." They are chronologically rather than biologically old. The process of aging is slow, progressive and persistent and it may or may not be "graceful." All tissues and organs in an individual do not necessarily age synchronously. In senescence homeostasis is diminished. Senility implies physical defects and degenerative conditions accompanied by social maladjustment and by impairment of intellect, emotions and sustained effort.

#### IMPORTANCE OF GERIATRIC SURGERY

Geriatric surgery is surgical therapy for the aged. Invalidism is increased with advancing age. Dublin's<sup>2</sup> statistics show the following figures:

TABLE I

Ages	Invalids per 1,000
All ages.....	11
65-74.....	53.5
75-84.....	72.7
Above 85.....	106.2

The problem of the care of the aged is becoming more and more important as life-span increases. Based on the latest census figures, there was a 7.2 per cent increase in population between 1930-1940. In the same period there was an increase of 35 per cent of persons over 65 years of age. In 1940, life expectancy was 63 years, and in 1960 it should reach 68 years. It is estimated actuarially that in 1980, 40 per cent of the population will be over 45 years. Hence the health, social, economic and political significance of increase in life-span must be stressed.

In various parts of the country funds have been provided for research in gerontology, with special reference to its pathology and biochemistry. The ultimate goal is the promotion of longevity, with usefulness, reasonably good health and youthful stamina. It is important to "add life to years and years to life."

#### GENERAL CONSIDERATIONS

In the broad sense, the problems which are presented by surgery for the aged are produced by accompanying medical conditions and their complications. The most important are those found in the cardiovascular and renal systems. Large numbers of patients are also debilitated and dehydrated. These conditions are caused chiefly by nutritional failure due to inadequate diet, faulty assimilation and elimination, avitaminosis and poor water balance. All of these may be increased by the patient's inertia and by poor supervision of his regimen. Attention to general hygiene, diet and supportive therapy, in order to improve function and to produce better chemical, water and vitamin balance, create a greater sense of well-being which is a necessary preparation for operation. Early postoperative out-of-bed and ambulatory supervision have been pursued in selected cases. As a result, pneumonia,

## GERIATRIC SURGERY

circulatory failure and pulmonary embolism have been minimized, morale has been strengthened and convalescence shortened. Early motion, frequent change of position and deep breathing have been encouraged.

### INTERDEPENDENCE OF SURGERY AND MEDICINE

In geriatric surgery especially, it is important for the surgeon to have a good concept of general medicine and the basic sciences. With the advent of specialization and the limitations placed on physicians by specialized organizations and Boards, there has been an unfortunate tendency for technical specialists to run away from medical problems and to abandon the use of the stethoscope and the pleximeter finger. It is necessary for the surgeon to feel the responsibility of the relationship of medical consultation and corroboration. These medical problems very often determine the plan of surgical procedure, the preoperative and postoperative treatment and the most suitable methods for rehabilitation.

### INDICATIONS FOR OPERATION

Operative intervention in the aged should be considered when surgical disease is an immediate or future threat to life and when such disease produces continued discomfort, pain, disability, economic loss and interference with comparatively normal routine. Operative therapy may give a welcome symptomatic improvement, permanent relief or cure. The decision as to operative indications, their type and magnitude must necessarily come from what is known as surgical judgment. This is developed from cumulative experience and honest and analytic appraisal of facts.

The most frequent surgical conditions in the aged on our surgical service are infections, malignancy in the gastro-intestinal and urinary tracts and in the reproductive system, in the breast and skin, obstruction in the gastro-intestinal and urinary tracts and in the biliary system, calculus disease, ovarian cyst, uterine fibroids, prolapsus uteri, hernia, hydrocele, appendicitis, bladder diverticulum, hemorrhoids, varicose veins, fractures (especially those involving the neck of the femur), gangrene of the lower extremities resulting from peripheral vascular disease, decubitus ulcers, contractures at the knees, fistulae and sinuses.

### THE SURGICAL RISK

Old age does not necessarily preclude surgical procedures which might save or prolong life or produce continued physical comfort or relief of pain, and economic, functional and social usefulness. How easy it is and, strangely enough, how difficult it can be for old people to die! The tremendous strides which have been made and are continuing to be made in medicine and surgery necessitate the abandonment of outdated defeatist attitudes and the adoption of a more progressive and optimistic outlook in geriatric surgery. Such an outlook has encouraged hazardous procedures for the aged after considered

judgment, Staff consultation and proper evaluation of the facts on the hospital chart. The fear and implication of mortality statistics have not been deterrents to surgical therapy when there was hope for improvement or cure. The family and, in selected instances, the patient have been made to understand the surgical risk and the end-result which could be expected.

In evaluating the surgical risk, a number of factors must be considered. The most constant one is diminished reserve in the aged. The choice of operation and its magnitude must be balanced against the expected beneficial results, the current enjoyment of life and life expectancy without surgery. As a general rule, heredity and the previous methods of living help to determine the operative risk. Shock is insidious and easily produced and recovery from shock is highly speculative and slow. The increased dangers from anesthesia, infection and retarded repair are evident. Conservatism by delay at the wrong time may be very costly. This is especially true in spreading infection and in obstruction in various organs.

TABLE II  
OPERATIVE MORTALITY STATISTICS

Source	Age-Groups	Number of Major Operations*			Mortality Per Cent		
		Males	Females	Total	Males	Females	Average%
Goldwater Memorial Hospital	61- 70	152	50	202	15.78	22.	18.89
	71- 80	148	47	195	24.18	27.6	25.89
	81- 90	38	12	50	44.73	25	34.86
	91-100		2	2			
	101-110		1	1			
	Total	338	112	450			22.66
Bailey <sup>3</sup> .....	60-84			185			7.6
Parsons <sup>4</sup> & Purks.....	60 and over			100			17
Clagett <sup>5</sup> .....	60 and over			1204			9
Hay <sup>6</sup> .....	70 and over			536			16.6
Evans <sup>7</sup> & Key.....	60 and over			83			7.2
Grand total.....				2558	Grand average, %.... 13.1		

\* The emergency operations were 12.88% of the total number.

#### TOLERANCE TO OPERATIVE THERAPY

With increasing experience in geriatric surgery, it has become evident that the aged stand operation far better than is generally believed. It is fair to state that in our patients the surgical risk has been very bad. The majority have been in other municipal hospitals for long periods of time or they have been guests of a municipal home. Others have been under treatment for chronic illnesses on the medical or neurologic wards of the Goldwater Memorial Hospital. In many instances the pathologic state on admission was so far advanced that patients were moribund, or nearly so.

Table II indicates our operative mortality statistics. They include only those patients who died within one month after operation. The table also gives comparative mortality statistics from other clinics. The higher rate

of mortality among the patients at the Goldwater Memorial Hospital is explained by the above mentioned conditions.

For comparison, Table III illustrates the mortality rate in all age-groups in various clinics after typical major procedures.

TABLE III

OPERATIVE MORTALITY STATISTICS OF STANDARD SURGICAL PROCEDURES IN ALL AGE-GROUPS IN VARIOUS CLINICS

Source	Type of Operation	Mortality Per Cent
Cattell <sup>8</sup>	Biliary tract surgery	1.1
Dick <sup>9</sup>	Nephrectomy	2.2
Colp, <sup>10</sup> <i>et al.</i>	Subtotal gastrectomy	4.26
Watson <sup>11</sup>	Hernioplasty (for non-strangulated hernia)	1
Leigh, <sup>12</sup> <i>et al.</i>	For intestinal obstruction	13.2

A comparison of the mortality statistics in Tables II and III indicates that the operative risk in the aged is not prohibitive. The contributing factors for these encouraging figures are the modern concepts of preoperative investigation and preparation, refined technics and stage operations when indicated, better anesthesia and better postoperative care. The production and maintenance of comparatively normal chemical, water and vitamin balance and the adequate improvement of organic medical conditions by appropriate therapy all help to diminish morbidity and mortality. Long periods of preparation for operation, accompanied by the use of vitamins and a high protein diet and amino-acids, are frequently necessary. The use of blood transfusions is an established routine, but overloading of the vascular system with fluid is to be avoided, especially in those with diminished cardiac reserve. In elective procedures, bedrest for several days before operation is advisable.

Technics should be as simple as possible. Speed is essential, but not at the expense of minimal operative manipulation and trauma. Leonard Wright<sup>13</sup> stated in "Display of Dutie," written in 1589: "In a good surgeon a hawk's eye, a lion's heart and a lady's hand." Careful hemostasis is important especially in those patients with arteriosclerosis. Through-and-through abdominal sutures can be life-saving when speed is essential and the patient's condition has suddenly become critical.

#### CAUSES OF OPERATIVE DEATH

Pathologic conditions in the aged are so multiple and varied that it is often difficult to state the cause of operative deaths, even after autopsy. The clinical impression of the major contributing causes of such deaths is heart failure and/or bronchopneumonia accompanied by pulmonary edema. This impression is supported by a review of 55 autopsy records of postoperative patients between the seventh and tenth decades. This showed that all had some type of myocardial or valvular involvement, with frequent cardiac dilatation, and that 39 (70 per cent) had bronchopneumonia and pulmonary edema. In addition, all the patients had varying degrees of coronary sclerosis

with old myocardial damage. There was a recent myocardial infarct in only one instance. These observations seem to indicate that coronary sclerosis *per se* is not a contraindication to operation.

Among other more frequent causes of operative death are shock, sepsis, pericarditis and peritonitis; pyelonephritis and uremia in urologic cases, cerebral thrombosis, pulmonary embolus, malignant metastases, miliary tuberculosis and nutritional and hepatic failure.

#### PSYCHIATRIC CONSIDERATIONS

The old patient is apt to be stubborn and resistive and grooved in an habitual way of living. Life-long abnormal traits are usually emphasized in old age. These traits call for limitation of restrictions, patience, tact and a bedside manner which radiates optimism. This optimism is strengthened by interviews with ministers in the various religious groups. This practice has been found to be most valuable. The quick change for coöperation is sometimes astonishing, especially in obtaining consent for operation. A persistent lack of coöperation, along with eccentric traits, habits and mannerisms implies the presence of a psychiatric condition. Its recognition is important. If behavior and abnormal habits are extreme, the patient may be misunderstood, the morale of surrounding patients suffers and ward discipline is upset. Among the more usual psychiatric disorders are those caused by cerebral arteriosclerosis and cortical atrophy, senile dementia or involutional melancholia. Some of the manifestations of these conditions are mental rigidity, irritability, intolerance, memory defects, confusion of ideas, disorientation, lack of assurance, tremors, auditory and visual hallucinations, paranoid trends, assaultiveness, and foul fecal and urinary habits. Under such circumstances, transfer to a psychiatric institution is not only advisable but mandatory.

#### ANESTHESIA

A major factor in the increasing success of geriatric surgery is improvement in anesthesia. The highly specialized anesthetist is well trained in the basic sciences, especially physiology and chemistry. He understands the newer concepts of shock and the various methods for its prevention and therapy. The choice of *the* anesthetist is important. Anesthesia apparatus delivers inhalants scientifically and with reasonable accuracy. The choice of anesthesia is made after consultation between the surgeon and anesthetist. Preliminary sedation minimizes anxiety and shock and reduces the amount of anesthesia necessary.

The success of local anesthesia is dependent on its technical application and the patient selectees. For example, local anesthesia is highly satisfactory in procedures for decompression of abdominal viscera, the repair of inguinal herniae and the excision of superficial growths. The use of novocaine 1 per cent, without the addition of adrenalin, is to be preferred because the adrenalin tends to make the patient excitable and nervous. It is also better to detect

and to tie bleeders than to promote temporary blood vessel constriction by adrenalin.

Spinal anesthesia, with its various refinements, is very helpful in prolonged lower intra-abdominal procedures and in amputation of the lower extremities. It is contraindicated in patients with organic disease of the central nervous system and in those with deformity or arthritis of the spine. It is also contraindicated in those with marked hypertension or nephritis, where the accompanying drop in blood pressure may cause an acute suppression of renal function.

All inhalation anesthetics should be accompanied by ample oxygenation. Cyclopropane seems preferable to all other inhalants. It is least toxic and produces the smoothest postoperative recovery. Ethylene has been discontinued because of its explosive risk and tendency to produce anoxia. Ether, administered by the open drop-method, is still a good supplemental and stimulating anesthetic. Nitrous oxide and oxygen has its usefulness for short anesthetics.

Avertin anesthesia in the aged should be used with a great deal of caution. It is contraindicated in those with diminished cardiac reserve, liver disease, chronic pulmonary conditions and in those who are in shock. If the patient does badly during operation, it is difficult to prevent further action of the avertin and he may just "sleep away."

The intravenous use of sodium pentothal for short operative procedures is gaining favor.

Crymal anesthesia for lower extremity amputations offers a paradox. The technic of its application calls for the obliteration of the blood supply to the extremity by a tourniquet high up in the thigh and for the freezing of the extremity by encasement in ice. These extend over a period of from two to three hours. It is to be expected that the resulting tissue anoxia and its thermal insult at the site of amputation might produce gangrene or poor healing of the stump. These do not seem to occur. Tissue destruction is apparently no more marked than after other methods of anesthesia. If crymal anesthesia is properly carried out, amputation should be painless except that in some patients section and traction on the sciatic nerve produces transient pain. Frequent pulse, temperature and blood pressure readings, before, during and after the operation indicate remarkably little change in these readings from the normal of the patient. It is safe to conclude, therefore, that the operation produces a minimum of immediate or delayed shock. After crymal anesthesia, postoperative phantom peripheral pain is absent or minimal.

#### GENERAL OBSERVATIONS

Trauma frequently produces undue severity of a lesion and its accompanying ecchymosis. Pain sense, as a rule, is less than the pathologic lesion would seem to indicate. This is especially true in patients with neurologic conditions. There is a marked hyposensitivity to peritonitis, with minimal ab-



dominal muscular rigidity but the temperature is usually markedly elevated. As a result, clinical syndromes may be masked. A thin abdominal wall with lack of tone and panniculus imply prolonged malnutrition and/or hypoproteinemia and predispose to abdominal disruption and poor healing of suture lines. There are surprisingly few wound disruptions and infections, despite the fact that patients often remove their dressings. Postoperative recovery is usually smoother than is generally believed. A persistent drop in blood pressure is a grave sign. Postoperative pneumonia is usually of a diffuse bronchopneumonia type, with minimal or no chest signs, little if any cough and with elevated temperature. The only positive indication of pneumonia may be the roentgenologic findings. The sulfonamides and penicillin are well tolerated and very effective. Since severe medicinal depression diminishes oxidation, motility and secretion it is advisable to use caution in giving sedatives. Morphine and its derivatives can be given in smaller than the usual doses, but demerol as a substitute is becoming more popular. Postoperative use of the barbiturates should be avoided. They tend to cause mental confusion, disorientation and somnambulism. Chloral and bromides are preferable. In old people especially, hot, humid weather is a contraindication for elective procedures.

#### SUMMARY

1. Experience in geriatric surgery in very bad-risk patients over 60 years of age in a municipal hospital is described. In 450 major operative procedures, 13 per cent of which were emergency, the operative mortality was 22.6 per cent. These, combined with 2,108 major operative procedures in the aged in five other clinics produced an average mortality of 13.1 per cent for 2,558 cases. This rate is not prohibitive when compared with operative mortality statistics in all age groups from five clinics after various major operations. The aged stand operation far better than is generally believed. Advances in medicine and surgery have made this possible.

2. The classification of people past the age of 60 as chronologically or biologically old depends upon the degree of the degenerative processes.

3. Geriatric surgery is growing in importance because of progressive increase in life-span.

4. Familiarity with medical problems and the basic sciences in relation to geriatric surgery is necessary.

5. The surgical risk should not be a deterrent to operation when the surgical disease threatens physical comfort, comparatively normal routine or life.

6. The chief contributing causes of operative death are heart failure and/or bronchopneumonia and pulmonary edema.

7. Coronary sclerosis *per se* with secondary old myocardial damage without decompensation is not a contraindication to operation. Acute coronary occlusion after operation is infrequent.

8. General and psychiatric considerations and general observations in geriatric surgery are noted.

9. A major factor in the increasing success of geriatric surgery is the improvement in anesthesia. Consultation between the surgeon and anesthetist is important.

10. Geriatric surgery can "add life to years and years to life."

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## WOUND HEALING WITH LOW VITAMIN C LEVEL

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OUR FIRST EXPERIENCE in the treatment of war wounds was in the Italian campaign in November, 1943. The lines during the next few months were to remain relatively stable and the conditions offered many possibilities to study wounds. The diet of the soldier prior to admission had been uniform and simple. Fighting was in the mountains and the transportation difficult, so that a concentrated diet was necessary. It happens that all of the vitamin C content of this diet is contained in a form of lemon powder which is not relished by the troops and so usually discarded. An opportunity was offered to see the effect, if any, on the plasma levels of vitamin C and any correlation with healing of wounds.

Experimentally, a definite relationship has been established between wound healing and ascorbic acid intake in the scurvy-susceptible guinea-pig.<sup>1</sup> Taffel and Harvey,<sup>2</sup> in an excellent series of experiments, showed that the tensile strength of the stomach of the scorbutic guinea-pig was much less than the normal animal. In man the correlation has not been convincing. The recent literature reflects the amount of interest that has been shown in the subject. With its known prolonged absence producing the clinical picture of scurvy, an attempt has been made by many to correlate a lower intake of the vitamin and low plasma levels with less severe tissue alterations.<sup>3</sup> Minot<sup>4</sup> has stated that a normocytic anemia is produced by a deficiency of the vitamin. Liu<sup>5</sup> showed that the anemia occurring in a group of patients that had low ascorbic acid level responded only with administration of iron and not with ascorbic acid. The response was determined by a rise in erythrocyte and hemoglobin levels.

Resistance in infection and prevention of bleeding gums are some other properties that have been ascribed to this substance. Of particular interest to us has been the observations on wound healing as related to vitamin C. Ingalls,<sup>6</sup> one of the earlier investigators in this field, prepared the following table for vitamin C nutrition as based upon plasma determinations (Table I).

Most of the textbooks<sup>7, 8</sup> give the average level of human plasma as 0.70 to 1.0 mg. per cent.

Pijoan and Lozner<sup>9</sup> have recently written a summary on the physiology of vitamin C in man. They quoted the work of Butler and Cushman,<sup>10</sup> who determined that the ascorbic acid content of the white cell-platelet layer of centrifuged blood is probably the most accurate indication of prescorbutic status. The normal is 25 to 38 mg. per 100 cc. of this layer. Pijoan maintained himself on a low ascorbic acid intake for 20 months with 0.0 to 0.2 mg. plasma ascorbic level. The white cell-platelet layer, on the other hand, was always above the 25 mg. per 100 cc. An experimental wound at the end of this time showed normal healing. Crandon, Lund and Dill<sup>11</sup> showed that the normal healing of an experimental wound on a normal adult occurred

after the plasma ascorbic acid had been 300 for 44 days and the white cell-platelet layer was 4 mg. per 100 cc. It was after the white cell-platelet layer had been 300 for two months that a second wound failed to heal clinically, and, histologically, showed a lack of intercellular substance.

In this study it was possible to obtain the exact diet of the individual for 30 days prior to the receipt of his wound. It was found that in most incidences the diet was the same for much longer periods of time but one month was as long as most patients could recall the type of ration they had eaten.

The types of ration that were used by the subjects in this study are as follows:

TABLE I  
VITAMIN C NUTRITION AS BASED UPON PLASMA DETERMINATIONS

State of Vitamin C Nutrition	Plasma Ascorbic Acid Mg. Per Cent
Optimum:	
Saturation.....	2.00—1.00
Normal.....	1.00—0.70
Low normal.....	0.70—0.50
Suboptimal.....	0.50—0.30
Deficiency:	
Asymptomatic scurvy.....	0.30—0.15
Clinical scurvy.....	0.15—0.00

*Ration C.*—This is the simplest form of ration. Each meal is the same, and is packed in two cans. One contains either meat and beans, hash or meat and vegetable stew. A second can has biscuits, candy, sugar and a package of either cocoa, coffee, or lemon powder. The ration can be quickly heated and requires no equipment for preparation. The monotony is its principal disadvantage. The entire ascorbic acid content is in the lemon powder, which is provided in one-third of the cans containing biscuits. This is designed to give each man 70 milligrams of vitamin C daily. (The C ration has been subsequently modified.)

*Ration K.*—This is a similar type of field ration which is designed for the use of the individual. It is contained in small cartons that are easily carried by the soldier. It offers a further change in the foods for each meal. The main items are a can of meat and eggs for breakfast, cheese for lunch and a can of meat for supper. It, likewise, offers the ascorbic acid in the form of lemon powder. This is packed in the noon meal box. The amount is 60 milligrams.

*Five-in-One and Ten-in-One Rations.*—These rations, as the name implies, are issued in bulk to supply either five or ten men. They group their food supply and thus obtain a better variety of more palatable foods. Five different variations or menus are offered with this ration. It is combined with the issue of cigarettes, soap, and water disinfectant tablets. In the five-in-one type, fruit juice is given daily and the lemon powder is issued in only one meal of one menu. In the ten-in-one type, all menus contain

fruit juice powder. Both are calculated to give each man 75 milligrams of vitamin C daily.

*Theater "B" Rations.*—This type is used in the sections where troops are located in regular camp areas or in buildings. The facilities for cooking and storage of food are good. Many of the units are able to purchase fresh vegetables in the markets, but, in general, there is still a predominance of canned foods. The lemon powder is furnished in bulk and is to be added to the fruit juices which are served. This is the type of ration used for the various hospital installations in this area. The minimal intake of ascorbic acid is again calculated at 60 milligrams. This factor would vary markedly from season to season and in the manner of preparation of the food in the different installations.

The cases in this study were all admitted to the hospital during the latter part of February and the month of March, 1944. The only requirement was that they had been at the front for 30 days or longer. They were

TABLE II

SUMMARY OF THE EATING HABITS OF THESE PATIENTS

Number of patients eating three meals daily.....	78
Eating the entire amount of food of each meal.....	46
Eating occasional green food.....	26
Using the lemon powder occasionally.....	14
Using the lemon powder consistently.....	2

selected at random on admission. Information was obtained regarding the number of meals eaten, average part of each meal consumed, if the lemon powder were used, supplemental rations as regards green foods, *etc.*, estimated weight loss, bleeding of gums and appetite. At physical examination, the general state of nutrition, hydration, condition of gums and skin was noted. A record of the case, diagnosis, extent of the wounds and the hospital course was recorded. The tourniquet test was tried on many of the earlier cases but was abandoned. No hemorrhages were observed. A fasting blood sample was taken and within three hours a determination of the plasma vitamin C was made using the technic of Farmer and Abt.<sup>12</sup> Hemoglobin determinations were made using the chemical method of Wong.<sup>12</sup> Plasma protein and hematocrit values were determined by the copper sulfate specific gravity method, as described by Phillips, Van Slyke, *et al.*<sup>13</sup>

Of the 100 soldiers examined, 68 had wounds. The latter had an average of 2.6 wounds per patient. These were divided into 43 "mildly" wounded, *i.e.*, having usually one or two wounds of the soft tissue and 25 cases of "seriously" wounded, having extensive injuries and multiple wounds often associated with fractures. Thirty-two of the cases had trench feet and the others had miscellaneous diagnoses.

The average soldier in this group had ration C for nine days, ration K for nine days, five-in-one for seven days, ten-in-one for two days and ration B for three days.

Twenty reported their appetite as poor, 21 as fair, and good in 59. The information as regards weight changes is not reliable. An estimate only was obtained. For the 30 days prior to admission, 25 noted no change in weight, 21 had estimated a loss of five pounds and 21 were estimated at ten pounds. One had gained three pounds and two had stated their loss as 20 pounds.

No case of clinical scurvy could be demonstrated. There was encountered no unusual hemorrhage in the skin and the only abnormal condition of the gums was that usually seen with pyorrhea.

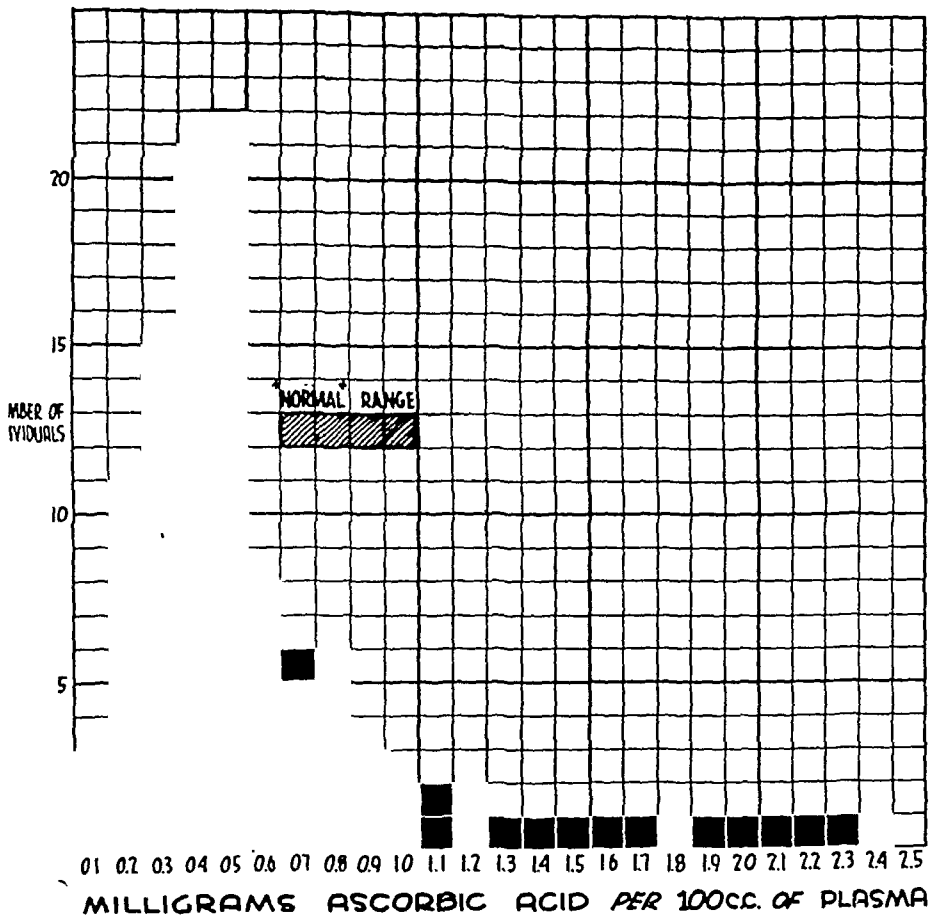


CHART I.—This shows the distribution of plasma ascorbic acid values for 100 soldiers.

The admission plasma vitamin C levels of the 100 patients varied between 0.1 mg. and 2.35 mg. per cent. We were unable to account for the latter unusually high figure. The next highest figure was 1.1 mg. per cent, and this soldier had been able to obtain two oranges a day for the month prior to admission. Seventy per cent were in the range of 0.2 to 0.5 mg. per cent. The mean level for the entire group was 0.631 mg. per cent. The results are shown in Chart I.

To determine if the diet in an installation would maintain a high fasting plasma ascorbic acid, ten men were selected at regular intervals from the roster of the hospital personnel. These men had been on a "B" ration for

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five months. The average level for the group was 0.585 mg. per cent. The lowest was 0.2 mg. and the highest 1.2 mg. per cent.

Determinations were repeated on 13 of the seriously wounded after a period of six weeks hospitalization. The results are shown in Table III.

TABLE III  
DATA ON REPEATED VITAMIN C DETERMINATIONS ON 13 PATIENTS

Patient	Vitamin C Level on Admission	Vitamin C Level after 6 Weeks
2.....	0.2	0.6
3.....	0.2	0.7
5.....	0.9	0.9
7.....	0.4	0.5
8.....	0.4	0.6
9.....	0.3	0.4
10.. ..	0.4	0.6
13.....	0.5	0.8
14.....	0.3	0.5
16.....	0.4	0.6
20.....	0.5	0.9
21.....	0.6	1.4
23.....	0.5	0.3
Average.....	0.43	0.68

Of the 43 less seriously wounded, or patients having operative incisions, only two failed to heal. In these it was necessary to perform additional closure of the wound or apply a skin graft to cover the defect. In the first of these failures, one-half of one wound separated, while another wound of the same size and severity healed promptly. The blood findings on admission were: ascorbic acid 0.2 mg. per cent, plasma protein 6.8 mg. per cent, hemoglobin 86 per cent, and hematocrit 40 per cent. The other patient had a secondary closure of a perforating wound of the left thigh which separated. An additional closure of the wound was successful. His blood findings on admission were: ascorbic acid 0.43 mg. per cent, plasma protein 7.87 mg. per cent, hemoglobin 111 per cent and hematocrit 54 per cent. One patient not included in the failures had an abscess of a puncture wound of the knee region on admission. The wound for incision and drainage of the infection healed promptly. The ascorbic acid level was 0.1 mg. per cent. Another complained of vague abdominal symptoms and epigastric pain. An examination of the gastro-intestinal tract by a barium meal showed intestinal patterns which were interpreted as "avitaminosis." His ascorbic acid level on admission was 0.5 mg. per cent. The course of another in this series was complicated by acute hepatitis associated with jaundice.

Of the 25 seriously wounded patients six failed to heal primarily. It is of advantage to report these cases more in detail.

### CASE REPORTS

**Case 1.**—A 21-year-old soldier was admitted, April 4, 1944, with extensive wounds of the right lower thigh, chest, a penetrating wound of the right foot and traumatic amputation of the left leg, sustained March 25, 1944. The ascorbic acid level on admission was 0.2 mg. per cent. The second day after admission the wounds of the right



thigh were closed and a graft applied to the stump of the left leg. All wounds of the thigh healed promptly. The graft was lost at the end of two weeks. On April 27, the left leg was reamputated and healed under penicillin protection. The ascorbic level was 0.6 mg. per cent May 18, 1944.

**Case 2.**—A 19-year-old litter bearer was admitted, April 4, 1944, with penetrating wounds of the left shoulder, comminuted fracture of the scapula, extensive wounds of the left chest and buttock, a midhigh amputation of the left leg. On admission, ascorbic acid level was 0.2 mg. per cent. Following a delayed primary closure of the wounds April 6, all healed except the one of the left stump. Under penicillin protection April 24, an additional closure and skin graft operations were done. May 10, there were a few small unhealed areas. The ascorbic acid level on May 19 was 0.7 mg. per cent.

**Case 3.**—A 20-year-old rifleman was admitted, April 4, 1944, having been wounded in action March 26. The diagnoses were: (1) Extensive wounds of the right thorax, with a fracture of the tenth rib and penetration of the diaphragm, liver and kidney; and (2) multiple wounds of the right arm, with extensive comminution of elbow joint. Ascorbic acid level on admission was 0.5 mg. per cent. April 6, all of the wounds were closed. Two days later the distal humerus and the proximal portions of the radius and ulna were resected. All wounds healed except for a slight disruption of the abdominal wound. No sutures were required to close the defect. No further blood determinations were done.

**Case 4.**—A 27-year-old artilleryman sustained, February 19, 1944, a severe wound of the inguinal region dividing the femoral vein and artery. His ascorbic acid level on admission, February 22, was 0.5 mg. per cent. February 25, a delayed primary closure was done. This promptly separated. March 23, the lumbar sympathetic ganglia were removed from the wounded side and this wound, likewise, became infected and separated. The ascorbic acid level at the time of this complication was 1.1 mg. per cent. He was returned to the States on June 1, at which time his wounds remained unhealed.

**Case 5.**—This case was of unusual interest. A 24-year-old infantryman was admitted April 4, 1944. Admission level of ascorbic acid was 0.5 mg. per cent. He had wounds of the left shoulder and both scapular regions, wounds of the lumbar regions and the elbow. April 5, all wounds were closed and healed except that of the left shoulder. May 5, an additional closure of the shoulder wound was done. At the same time a pigmented nevus was removed from a clean area of the ankle. May 18, both wounds completely separated and, as described by the operator, "without apparent reason." The ascorbic acid level at the time of the second separation was 0.9 mg. per cent.

The level of the ascorbic acid for the group of wound failures, on admission, was 0.37 mg. per cent. The average admission level for the remainder of the seriously wounded soldiers, who healed promptly, was 0.45 mg. per cent. Of the 25 seriously wounded 21 returned to the States. In no instance were they evacuated due to failure of wound healing but because of loss of an extremity, severe chest injuries, brain injuries or extensive fractures requiring prolonged treatment. In the group of seriously wounded it is significant that only one or two wounds failed to heal while others healed readily.

Plasma ascorbic acid levels were determined on nine patients that had wounds that failed to heal. Some of these wounds had been closed several times by different operators. Most of this group were hospitalized for two to three months. The first three cases were during the spring months and

the latter six were during the fall, following a period in which the hospital diet had contained fresh fruits and green vegetables. Table IV is a summary of the findings.

TABLE IV

ASCORBIC ACID LEVELS ON PATIENTS WITH REPEATED WOUND FAILURES

Wound of:	Date of Admission	No. of Operative Closures	Ascorbic Acid Mg. Per Cent	Date of Determination
Lumbar region.....	Jan. 21	3	0.50	Apr. 13
Lower leg.....	Jan. 30	2	0.50	Apr. 13
Upper arm.....	Jan. 26	3	0.80	Apr. 13
Thigh.....	May 26	5	1.26	Nov. 20
Upper chest.....	Sept. 23	4	1.31	Nov. 20
Posterior chest.....	Oct. 25	2	1.44	Nov. 20
Posterior thigh.....	Oct. 13	3	0.64	Nov. 20
Lateral thigh.....	Oct. 17	2	1.11	Nov. 20
Posterior chest.....	Oct. 17	3	0.84	Nov. 20

DISCUSSION.—In this study, 100 soldiers were selected on their admission to the hospital. These men for at least one month had been at the front on a ration of concentrated foods. Practically no green foods were obtained. Their entire source of vitamin C was ascorbic acid contained in the lemon powder. This was discarded by all but 2 per cent of the troops. The fasting plasma ascorbic acid levels were obtained the first day after admission and were found, in general, to be below the “normal” minimal range. The diet in this hospital was unable to raise the level appreciably to so-called “normal” levels, as shown by repeat determinations and determinations of hospital enlisted personnel.

Of the 100 men, 68 had wounds and eight of this number had interference in healing and required an additional operative procedure to close the skin defect. This is a failure in 11.7 per cent. Nine patients having repeated wound failures showed no reduction in the plasma ascorbic acid levels.

With added experience in the closure of war wounds it has become possible to avoid many of the causes of failure of wound healing. Most of the instances in this group were associated with infection. It is interesting to note that the one case in which no explanation could be given for the separation of a “clean” wound the ascorbic acid level was 0.9 mg. per cent. Improvement in delayed primary closure of wounds has followed the following principles: Early and adequate débridement; use of incisions at the time of débridement that readily lend themselves to closure, proper splinting of the wounded part; early (four- to five-day) closure of the wound in the operating room at the time of the first dressing by suture or skin graft; use of fine nonabsorbable suture material closing the skin only and without tension; the maintenance of normal blood constituents especially as regards the plasma protein, hematocrit and hemoglobin levels; and the intelligent use of penicillin and the sulfonamides. We have found during the past year that the improvement in wound healing has been from these measures. In general, no therapeutic doses of vitamin C have been given. The diet of the soldier has remained the same, yet there has been a continued decrease in

the number of wound failures. This has improved until Kirtley and Triabue,<sup>14</sup> of our group, report an incidence of 4.2 per cent of infections in 71 wounds having delayed primary closure four to six days after débridement. Crutcher<sup>15</sup> collected a series of 100 consecutive cases closed from three to ten days following débridement, with separation in only two cases. Those with mild "stitch" abscess were not included.

## SUMMARY

1. One hundred patients were studied that had been on a diet for one month, or longer, that was deficient in vitamin C.
2. No clinical evidence of vitamin C deficiency was found.
3. Plasma ascorbic acid values on admission varied between 0.1 mg. to 2.4 mg. per cent. The mean level was 0.63 mg. per cent. Sixty-nine per cent of the patients were within the range of 0.2 mg. to 0.5 mg.
4. Of a group of 43 less seriously wounded, only two patients had wounds that failed to heal.
5. Of a group of 25 seriously wounded, there were six failures.
6. Nine selected patients, with repeated wound failures, had plasma level findings of 0.5 mg. to 1.44 mg. per cent, with a mean level of 0.93 for the group.
7. No relationship between plasma ascorbic acid levels and wound healing was observed.

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## ANNOUNCEMENTS



### DEPARTMENT OF ANESTHESIA AT MCGILL UNIVERSITY

Recently there has been created in McGill University, Montreal, Canada, a Department of Anesthesia.

The objects of this newly-established centre of learning for anesthesia are: (1) to improve the teaching of anesthesia to the undergraduate students in Medicine; (2) to increase the opportunities for learning anesthesia among the internes of the hospitals connected with the university; (3) to conduct a three-year Diploma Course in Anesthesia; and (4) to develop investigation in anesthesia in the Clinic and in the Laboratory from the point of view of interrelationship, and, as well, in an interdependent fashion with the University's other departments.

It is considered that THE CENTENARY OF ANESTHESIA is being celebrated in a practical manner, and an international attitude is being adopted at the very beginning.



### THE EDWARD D. CHURCHILL LECTURE FOUNDED BY THE EXCELSIOR SURGICAL CLUB

A GROUP OF SURGEONS, who formerly served as members of the U. S. Armed Medical Corps in the North African and Mediterranean Theaters of Operations, recently organized The Excelsior Surgical Club. Patterned somewhat along the lines of the Eclat Club which, in a comparable manner, grew out of World War I, The Excelsior Surgical Club has as its objectives the promotion of the social intercourse of the members and the advancement of their knowledge of the science of surgery.

A principal and outstanding activity of the Club is to be the Edward D. Churchill Lecture honoring the former Surgical Consultant of those Theaters, Dr. Edward D. Churchill, John Homans Professor of Surgery at Harvard University. The Lecture, to which the medical public will be invited, will form an integral part of each annual meeting. The Club plans that each Lecture will be a foremost scientific presentation. To that end, Dr. Alfred Blalock, Professor of Surgery, Johns Hopkins University, has been secured to give the first Churchill Lecture at the first regular meeting of the Club in Boston on October 25-26, 1946.

# BRIEF COMMUNICATION

## MODIFIED BAKEŠ COMMON DUCT DILATORS

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NATURE has laid a trap for the surgeon by placing the lower end of the common bile duct in such an inaccessible position that stones cannot be seen nor easily felt. Indirect instrumentation is required for their removal with scoops or forceps after which there is always the question if any remain. This may be tested by the catheter-saline method of Cheever,<sup>3</sup> or by probing the duct to test its patency. The instrument designed by Bakeš is very useful for this purpose, for the smallest size (3 mm.) makes an excellent probe and the larger

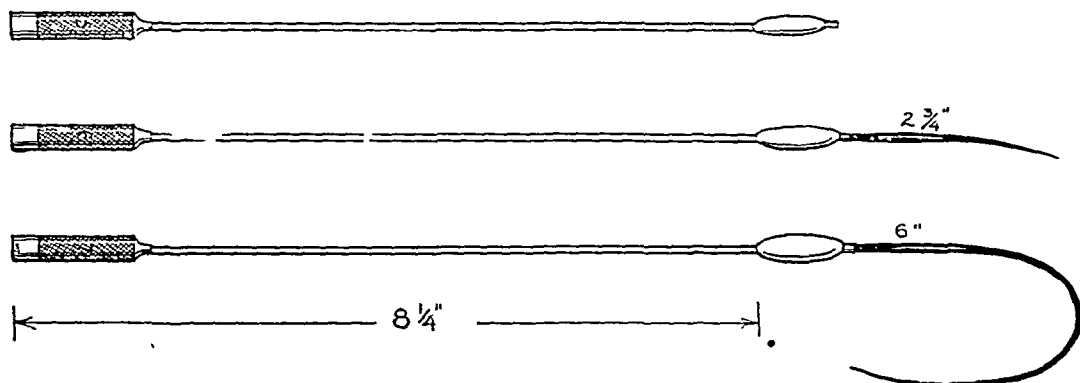


FIG. 1.—The Bakeš dilators as modified to include a filiform. The type of thread, the short and the long filiforms are shown from left to right. The flexible handle has been lengthened to 8.25 inches for greater ease in manipulation.

ones (4 to 6 mm.) assist in palpating the duct and sounding the ampulla. The operator may locate a stone by feeling along the duct as the dilator is slowly passed down it. He may define the borders of the ampulla of Vater quite accurately by placing a dilator in it and feeling through the anterior duodenal wall. Finally, the passage of the dilators into the duodenum sounds-out the size of the ampulla.

One fault of the Bakeš dilators is the lack of a guide to the ampullary orifice. This occasionally leads to their being caught in a false passage or in a mucosal fold and not passing into the duodenum, giving the erroneous impression of duct obstruction. The obvious solution of this difficulty is to attach a filiform to the end of the dilator to act as a guide. Desiring this, the author asked V. Mueller and Co. to make dilators from 3 mm. to 7 mm. size (Fig. 1) with a standard thread. The ordinary filiform used in urology is 12 inches in length, which is too long for this purpose. Two special filiforms are available; a short 2.75-inch (7 cm.) size and one that is six inches long.

The short one is fastened to each dilator before it is passed. The six-inch filiform may be left with the tip in the duodenum as each successive dilator is attached to it just as is done with a filiform and followers in urology.

The metal base of the filiform when attached to the dilator makes the rigid part of the instrument slightly longer. This is a little awkward with a high opening in a common duct tucked up under an overhanging liver, for it is harder to make the turn into the duct. However, this occasional disadvantage is slight in comparison to the benefits derived from having a guide to its passage.

Bakeš called this instrument a dilator,<sup>2</sup> and he, and others,<sup>1</sup> used it for stretching the ampulla of Vater. However, the experiments of Zollinger, Brauch, and Bailey<sup>4</sup> have clearly shown that this not only causes edema, hemorrhage, scarring, and increased intraductal pressure but also does not give any permanent enlargement of the opening. No instrument larger than 7 mm. (22 F.) should be passed through the ampulla, and even this size should not be used if any force is required.

#### SUMMARY

The Bakeš dilator is an exceedingly valuable instrument for exploration of the common duct and ampulla of Vater. It is modified to include a filiform in order to expedite its passage into the duodenum.

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## BOOK REVIEWS

**PATHOLOGY IN SURGERY.** By Nathan Chandler Foot, M. D., Professor of Surgical Pathology, Cornell University Medical College; Surgical Pathologist, New York Hospital. 500 pages, 368 illustrations in black and white, and 20 subjects in full color on ten plates. Philadelphia, London, Montreal, J. B. Lippincott Co., 1945.

ONE of the most interesting and important developments in American medicine during the past 20 years has been the establishment of the various Specialty Boards and the effect these have had in raising the standards of specialty education and practice. Most of the boards in the field of surgery and diagnosis require of their candidates a certain amount of training in the pathology of surgery, and include this subject in their examinations. Inevitably, this has led to a demand for postgraduate study in this topic—a demand which is becoming increasingly difficult to meet because of the dwindling number of competent teachers of pathology and the dearth of satisfactory texts of surgical pathology. Therefore, it is a pleasure to welcome this handsome volume from the pen of a leader who is known for his technical contributions and the breadth of his ripe knowledge.

Doctor Foot has not attempted to cover the entire field of surgery, and those who seek to know in detail the full pathology, for example, of the skin, nervous system and organs of the special senses will not find it here but must consult special monographs dealing with those subjects. Nor does he do more than touch upon some features of general pathology, which he feels are adequately dealt with in such standard texts as Karsner's "Human Pathology." He wishes his monograph to be regarded as ancillary to that excellent work, and Lippincott's have used the same easy reading format in manufacturing the present volume.

The medical student, the practicing surgeon and general pathologist will find this monograph a most valuable adjuvant to the study and interpretation of the pathology of the surgical diseases. As with any attempt to compress an enormous body of knowledge within the covers of a single volume, the expert will find some omissions, which he may regret, and occasional statements with which he will not be in full agreement yet, on the whole, it would be an act of invidious pejection to single these out when the work, as a whole, is of such a high order. Most of the fundamentals will be found here and the references will serve to guide those seeking more detailed information, although some of them are not as recent as they might be. This reviewer who is well acquainted with the multiple facets of Doctor Foot's versatility is happy to be afforded the opportunity thus publicly to offer his congratulations upon the appearance of this latest example of his lucubrations.

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**Textbook of Obstetrics.** By Henricus J. Stander, M.D. 9th Edition, D. Appleton-Century Co., New York, 1945.

WITH THE PUBLICATION of this retitled edition, little remains of the original text which was first published in 1903 and has been constantly revised, rewritten, reillustrated and modernized through nine editions and 46 printings. Every effort has been made, by the authors and publishers to improve the book in each edition, to the end that it might maintain its reputation as an authoritative presentation of obstetrical principles and the most modern guide to conservative obstetrical practice. The final result of this truly amazing modernizing process, the 9th edition, practically constitutes a new textbook—Stander's Textbook of Obstetrics.

To write a worth while textbook requires that the author shall be a good teacher—the better to plan consecutively; think logically; write clearly and concisely; and where

illustrations are to be employed, illustrate intelligently. This volume with its 1,287 pages of written text and nearly 1,000 illustrations, many in color, demonstrates the validity of these statements.

The general physical plan of this present edition differs quite radically from the previous editions of the William's Obstetrics in that the various subjects are presented in sections and subheadings instead of chapters. This idea seems reasonable because by this system there should be no confusion to either teacher, student or practitioner who wishes to utilize basic principles, didactic instruction or clinical procedures—singly or in combination. Furthermore, in order to facilitate and simplify reading matter, small type is employed to more sharply separate historical or purely theoretical considerations from the main text—a time-saver for the busy practitioner or the hard pressed undergraduate student. Likewise, the indexing system has been improved—made more readily workable.

It has been very aptly said that the illustrations in a textbook either make it a "best seller" or relegate it to the bookseller's shelf. This, it seems to this Commentator, is particularly true of obstetrical textbooks; and for two very good reasons: (1) basic obstetrical facts, *e.g.*, anatomy, embryology, physiology, pathology, *etc.*—can better be elucidated through good illustrations; and (2) obstetrical operations can be demonstrated much more satisfactorily through the medium of graphic drawings, made by a competent artist. Stander's illustrations are distinctly superior. They are the work of well-recognized medical artists; they are of sufficient size to give real instructional detail; and are so numerous as to almost constitute in themselves an obstetrical atlas. Those by the late Max Bröedel, the master medical illustrator, deserve special mention. Indeed, the author of any textbook containing Bröedel illustrations—father or daughter—is most fortunate.

Throughout this 9th edition, the author has kept the undergraduate student, as well as the practitioner in mind, deleting and adding such material as would make for completeness, readability and up-to-the-minute information. Among the outstanding sections might be mentioned those on the management of normal pregnancy with particular emphasis on the adequate antenatal care; the conduct of normal labor; the pathology of pregnancy; abnormal pelves; particularly the sections on clinical and morphologic classifications and clinical and roentgenologic pelvimetry; the management of obstetrical difficulties; and the pathology of the puerperium. The importance to the obstetrician of anesthesia; the toxemias of pregnancy; the management of hemorrhage, both ante- and postpartum; chemotherapy in the presence of acute infection; and the prevention and proper treatment of asphyxia neonatorum, cannot be over emphasized. These subsections are particularly well discussed, and if the practitioner and student, especially the former, would follow explicitly the information herein given, our present maternal and fetal morbidity and mortality rates could be still further reduced.

Bibliographic references are a necessity for the modern textbook. Stander's book is outstanding in this respect. However, this Commentator wonders whether the Author has not overburdened this portion of his book with quite a number of outdated references. There are a total of 106 pages of references, some old; some "middle-aged," and literally hundreds that are strictly up to date. The latter, without question, being indispensable in usefulness and value. On the other hand, would it not be more in keeping with the general modernization plan of the volume to sift out a goodly number of these old references? For example, there are 147 references on the Anatomy and Physiology and Development of the Ovum; 209 for the physiology of pregnancy; and 297 on the toxemias of pregnancy. It seems reasonable that not a few of these particular references might be deleted without detracting from the completeness of the section to which they pertain. The same comment could be applied to other sections of the book. However, it is without doubt true that if one prefers a well-nigh complete bibliography following every section of any given textbook, this 9th edition of Stander's Obstetrics is "tops." It unquestionably gives ready access to a veritable mass of obstetrical information, as well as many allied subjects, which may or may not be indispensably useful depending upon the requirements of the reader and the whim of the publishers.



Incidentally, the publishers of this volume have performed an excellent job. Under wartime conditions, it required much planning and "architectural" skill in bookbuilding to add all the necessary new material to the book and keep within the government's regulations and limitations on paper, ink, printing and binding—not to mention labor costs. It was no simple task to publish a textbook of this character and size, containing nearly 1,000 illustrations, many in color, and keep the selling price at a reasonable figure. All this, the publishers have accomplished in a commendable manner.

In conclusion, it may be well said that Stander's Obstetrics is distinctly outstanding. No one except a logical thinker and an experienced teacher could have performed such an exacting task. In it the undergraduate and postgraduate student; the general practitioner or the specialist has a readable; modern; conservative; authoritative; and splendidly illustrated textbook; which is offered at a price that does not unduly "strain" anyone's budget. It's popularity should continue at an ever increasing rate, which in turn will serve to promote better obstetrics and thus help to continue the downward trend in our maternal and fetal morbidity and mortality rates.

HARVEY B. MATTHEWS, M.D.

#### EDITORIAL ADDRESS

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